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**THE MECHANICAL HANDLING
AND STORING OF MATERIAL**

**THE
MECHANICAL
HANDLING & STORING
OF MATERIAL**

**Being a Treatise on the Automatic and Semi-Automatic
Handling and Storing of Commercial Products .**

**BY
GEORGE FREDERICK ZIMMER, A.M.INST.C.E.**

**WITH A FOREWORD
BY
SIR JOHN PURSER GRIFFITH, M.A.I., M.R.I.A.**
Past-President of the Institution of Civil Engineers

Third Edition, Thoroughly Revised
With over Eleven Hundred Illustrations

**NEW YORK
D. VAN NOSTRAND COMPANY
EIGHT WARREN STREET**

1922

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. "A man of wisdom,
With gentle handling, can bring in frame
That by curishness no twenty can tame."

William Forrest

("Orsello the Second," 1558).

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FOREWORD

TO THE

Third Edition of "Mechanical Handling and Storing of Material"

IN the Twenty-Fourth James Forrest Lecture, delivered before the Institution of Civil Engineers on the 24th October 1916, on

"THE DEVELOPMENT OF APPLIANCES FOR HANDLING
RAW MATERIALS AND MERCHANDISE AT PORTS AND OTHER
LARGE CENTRES OF TRAFFIC,"

I referred to the literature published on the subject, which showed "how much thought had been given, both at home and abroad, to the design and construction of such appliances." Mention was made of Mr Zimmer's book on "The Mechanical Handling and Storing of Material" as an English example, of which the 2nd edition had recently been issued.

The chief object of the Lecture was to show that the extension of such appliances must prove a potent factor in improving the conditions under which our workpeople live, by increased pay and shorter hours of work, with the natural corollary of better homes.

On these grounds I pleaded for the substitution of the term "labour-aiding appliances," in place of the familiar words "labour-saving appliances." It has been a great gratification to me that Mr Zimmer has adopted the terms "labour-aiding appliances" and "time-saving appliances" in his 3rd edition.

At no period of our history was the need so great for cheap food and clothing. The recent rapid advances in the rates of wages have not been accompanied by corresponding comfort in living. Instead of production increasing with the increase in wages, the result has been reduced output with increased prices and increased cost of living.

A vicious circle has been formed, and no real permanent improvement has been made in the condition of our workpeople.

No remedy can be found for this state of things unless the output of each individual worker is increased. No means of doing this exists except by the introduction of "time-saving" and "labour-aiding appliances," by which man is enabled to supplement his manual by his mental powers.

Mr Zimmer deserves well, not only of his professional brethren, but of all classes of the community, for having devoted so much of his time and thought to preparing this valuable monograph on "The Mechanical Handling and Storing of Material."

He has not only drawn from his own wide experience, but has placed before his readers selections from the best world-wide authorities, who have dealt with these cosmopolitan problems. The progress now being made in "labour-aiding appliances" is so rapid, and the improvements in details so great, that the time is ripe for a new edition of Mr Zimmer's great work.

I hope that he will be amply rewarded for his labours.

JOHN PURSER GRIFFITH,

Past-President, Inst. Civil Eng.

RATHMINES CASTLE,

DUBLIN, 1922.

PREFACE TO FIRST EDITION

THE following treatise on the Mechanical Handling of Material has not been the work of a day, a month, or a year. Its origin may be fairly dated back some twenty years ago, when I was professionally engaged in a branch of Engineering which in modern times has been peculiarly identified with the automatic handling of material. I am referring to Grinding of Material in general and Modern Flour Milling in particular. This branch, in which the mechanical handling of material both before and after treatment as well as in its intermediate stages is of the utmost importance, greatly attracted me. I began to make a special study of the different mechanical operations of handling; compiling tables, capacities, and speeds of elevators and conveyors for my own use, as well as such other information as was available. It was my lot to standardise such elevators as were used in flour milling, and the results of my work in this and other directions will be found in this work.

Later on, the field of my professional experience was considerably enlarged, and I found myself engaged in planning and designing installations with appliances for the Mechanical Handling of such raw materials as Ore, Coal, and Timber. Some of the results of my studies in this direction have been embodied in a paper which was read before the Institution of Civil Engineers on the 24th February 1903. The subject was, however, far too large to be exhausted within the limited compass of a paper, and I found, perhaps before I was fully conscious of the fact, that a treatise on a somewhat neglected though vast section of engineering had grown up in my hands. At first, with the diffidence natural to one who had never cultivated literature, I hesitated to put my notes in the form of a book, but these doubts vanished as I realised that no book existed in the English language on this important branch of engineering. Indeed, I have been unable to find a complete and connected treatise on the Mechanical Handling of Material in any language.

Therefore I set to work to reduce my rough notes to the orderly sequence of a formal treatise, embodying in carefully compiled tables a list of the results of my own experience, as well as all other available information respecting the capacities and speeds of machinery designed to handle material in substitution of or supplemental to the labours of human hands. I became a diligent collector of drawings and descriptions of such machinery and mechanical processes as are germane to

the subject of this work, and several hundreds of these drawings have been used to illustrate the volume.

I may say that I have made a point of personally studying, wherever possible, all systems of mechanical handling of material, and have with that view inspected every kind of installation described in these pages. It would, however, have been practically impossible for any one person to personally explore the whole of the immense field which is now covered by the mechanical handling of material. I have, therefore, supplemented my own practical studies and experiences by a careful perusal of all accessible authorities on this subject.

It gives me great pleasure to acknowledge my indebtedness to those authorities I have had occasion to consult. Much valuable information has been obtained from the *Proceedings* of the Institution of Civil Engineers, and also from the *Proceedings* of the Institution of Mechanical Engineers. I am further indebted to Mr J. D. Twinberrow, M.I.Mech.E., and to Mr Herbert Stone, M.I.M.E. Professor Buhle's papers in the *Zeitschrift des Vereines deutscher Ingenieure* I have consulted with profit; and am also under obligations to Baron Hanffstengel for his disquisitions on the mechanical handling of Ore and Coal in *Dingler's Polytechnisches Journal*. I have obtained much useful information on the subject of Tips from the late Sir W. G. Armstrong (Lord Armstrong). Also I must acknowledge my indebtedness to the late Herr Krupp. In the study of the Ropeway I have found helpful assistance in the monographs of Mr J. P. Roe, M.I. & S. Inst., and of Mr R. E. Commans, M.Inst.C.E., also of Mr W. T. H. Carrington, M.Inst.C.E. (engineer to Messrs Bullivant), and Mr H. H. Gass, the author of an interesting description of the Anaimalai Ropeway.

I am obliged for the kind and ready permission given me to make use of valuable information derived from the above sources, and should I have inadvertently omitted to acknowledge any source from which information has been obtained, I apologise, and will amend matters should the work be issued in a further edition.

If this book should serve as a guide to the Engineer and Manufacturer, I shall feel that much arduous work, snatched from the active exercise of an exacting profession, has not been spent in vain.

G. F. Z.

PREFACE TO SECOND EDITION

THE monograph on "The Mechanical Handling of Material," formerly written by me, has been out of print for some time, and in revising that publication for a new issue in the light of modern progress, it was found that the storing or stocking, and conversely, the reclaiming, of material (a subject which was formerly treated with secondary consideration) are now so much bound up with mechanical handling that it would be undesirable, if not impossible, to keep the two subjects apart. Under these circumstances I make the attempt in the present volume to deal with both handling and storing under the extended title of "The Mechanical Handling and Storing of Material."

The portion of the work devoted to the first subject, *Handling*, has been thoroughly revised and is now quite up to date, including chapters on the following new subjects—Coal Face Conveyors, The Mechanical Disposal of Ashes from Steamers, Mono-Rails and Telphers, The Handling of Coke from Coke Ovens, and The Handling of Coal by Pneumatic and Hydraulic Means; while *Storing* embodies all the methods in vogue for so dealing with minerals, chemicals, cereals, and other seeds, in conjunction with the mechanical appliances for assembling the materials as well as those for reclaiming them from stock.

It would have been practically impossible for any one person to explore, or be sufficiently conversant with, the whole of the immense field which is now covered by the mechanical handling and storing of material. I have, therefore, supplemented my own practical studies and experiences by a careful perusal and selections from all accessible authorities on this subject.

It gives me great pleasure to acknowledge my indebtedness to the Institution of Civil Engineers, the Institution of Mechanical Engineers, the American Society of Mechanical Engineers, the Verein deutscher Ingenieure, for much valuable information obtained

from their *Proceedings*; to such technical journals as *The Engineer*, *Engineering*, *Cassier's Engineering Monthly*, *The Iron and Coal Trades Review*, and also to other sources and authorities (acknowledged where they occur in the book) which I have found it most beneficial to consult. I am grateful for the kind and ready permission given to make use of information derived from these sources, and should I have inadvertently omitted to acknowledge any source from which information has been obtained, I apologise.

It should be pointed out that the importance of the subject matter of this volume increases daily, as technical progress is and has been increasing by leaps and bounds in the last decade. There is no factory now that can afford to do without machinery for handling and storing its raw materials and finished products if it is to be a commercial success. The national economy of the civilised world cannot do without the mechanical handling and storing of material, and in conclusion, the toll claimed from the ranks of labour by the European War, and the consequent shortage of hands, will force even those who are slowest to adopt modern means to replace the man by the machine wherever possible.

Let this be my excuse, if such be deemed necessary, for venturing again before the technical world.

G. F. Z.

82 MARK LANE, LONDON, E.C.,
January 1916.

PREFACE TO THIRD EDITION

SINCE a more able man has done me the honour of prefacing this Third Edition of "Mechanical Handling and Storing of Material," it will suffice if I confine myself to but a few words in which to outline the ideas which have guided me in the revision of the book. All matter of historical interest in the development of the handling art has been retained; obsolete installations or devices without such attributes have been deleted or replaced by more modern examples. Where the more recent installations do not differ materially from those already embodied in the book, no alterations have been made. With regard to the latest developments, only those have been embodied in the book which may be considered to be beyond the experimental stages and successfully in use.

In the two earlier editions it was necessary, in order to give a representative array of typical examples, to draw upon Continental and American practice. Such descriptions are now replaced by examples of British manufacture wherever possible.

The subject matter of each chapter is either arranged in chronological order, or in the rotation which marks the development of such machinery. The descriptions last given in each chapter are, therefore, the latest types of their kind.

It must be admitted that in some branches of the handling art new ideas are under consideration or in the experimental stages, but time alone can tell whether they will prove to be what the patentees, designers and manufacturers naturally anticipate.

With these reservations the Third Edition is as up to date as my knowledge of the subject enables me to render it.

G. F. Z.

82 MARK LANE, LONDON, E.C. 3,
June 1922.

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THE AUTOMATIC WEIGHING OF MATERIAL

CHAPTER XLIII

THE AUTOMATIC WEIGHING OF MATERIAL

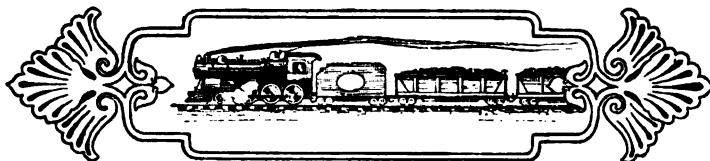
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THE MECHANICAL HANDLING AND STORING OF MATERIAL

CHAPTER I

INTRODUCTORY



When mechanical devices were introduced as aids to human effort, they caused a controversy concerning the influence of machinery upon the welfare of the human race which has been going on ever since. The workman's cry has always been that the substitution of manual labour by mechanical devices has diminished his opportunities of employment, and although the fallacy of this argument has been demonstrated from many quarters, the leaders

of the men have opposed, as inimical to their interest, those improvements which play a vital part in national economy.

In addition to their adverse attitude concerning the use of labour-aiding and time-saving machinery, the restriction of output has been advocated by the leaders of the Unions as a remedy for unemployment, but this again is unsound reasoning—plausible as it may appear at a casual glance—because the cost of production must be increased by such a policy, and enhanced cost spells diminished sales, which in turn result in unemployment.

The spirit of commercial unrest which is abroad to-day finds expression in the new Syndicalism which teaches that all manual wage earners belong to one class, and all the rest of the community to another class. In their crude conception it does not seem to have occurred to the intellectual leaders of the Syndicalist movement that it is only possible for a capitalist to renew his capital by selling the goods for the production of which he has paid wages, and that most of the buyers are themselves wage earners. The capitalist is, in fact, the channel for conveying goods from one wage earner who is paid for the labour of producing them, to another wage earner who pays for the pleasure of consuming them.

There can be no doubt in the minds of those who study the laws of national economy that the lower the cost of production the greater will be the sale of almost all commodities of life, as they become accessible to a larger circle.

If by the aid of machinery methods of manufacture can be brought to such perfection that what now takes a hundred hours of human labour to produce, will in future take only fifty, or even twenty-five, the result will be, provided the people be

satisfied with their standard of living, shorter working hours, rather than cheaper prices. The Americans, who are strenuous people, seem to prefer to work long hours and have a high standard of living. Nowhere have the methods of rapid production been carried further than in America, and nowhere are higher wages paid. The benefit of rapid production may, therefore, be either a higher standard of living or more leisure, or a compromise between these two.

"Imagine," says H. J. Brackenbury, "manufacturing processes so far improved that the amount of human labour required for the present production of the world were reduced by half. Many believe that the result of this would be to throw half the work-people out of employment. This would not be the true result. The true result would be that, other things remaining the same, every one would be as well off if the workers were paid the same wages as at present and worked for only half the time. This, then, is the goal to which we should strive; the goal which we ourselves shall not see, but which will nevertheless be finally reached. If the masters' and the men's leaders would make common cause, and work to this end, much benefit might be obtained in a short time."

If the working classes can be taught that their hostile attitude towards the introduction of machinery is against the technical and commercial progress of the country at large, and against their personal interest in particular, they will change their tactics and welcome modern progress.

It is not to be supposed for one moment that the inventors and users of mechanical handling devices are moved by any philanthropic motive, solely to better the lot of their fellow-creatures; neither on the other hand should it be maintained that the introduction of such plant was instigated to deprive men of the opportunity to work; but rather to lower the cost of production for the manufacturer's benefit and that of humanity as a whole.

It is important¹ to remember that the human machine, considered as a means of producing mechanical effect, is far too costly and too lacking in efficiency to be used for anything which can be done by manufactured power. Any idea that there is inherent dignity or merit in overstraining human muscle in a wholly undesirable and inefficient manner must be replaced by the certain knowledge that the true method of employing man is by the use of his trained judgment and skill in the control of manufactured power applied through properly designed machinery. Handling bulky and specifically heavy loads is very hard work, which often leaves the worker unduly fatigued, a condition only too likely to produce in him a brutal tendency, which result is by no means desirable.

From what has been said, it will be evident that the kind of labour which is most readily replaced by machinery is that of the untrained man, who works principally with his muscle, and that the performance of this portion of the world's work by machinery will mean that the man who is to earn his living by his labour must be capable of using his head as well as his hands, and learn at the same time how to do things at once less onerous and more valuable than formerly.

Technical progress can thus no longer be stigmatised as the enemy of labour, and where the introduction of mechanical handling devices has dispensed with a few labourers, their sphere of action has generally been transferred to more responsible and less laborious work.

¹ In an article entitled "The Replacement of Man by the Machine," by H. H. Supplee, in *Cassier's Magazine*.

The frequent strikes of workmen, generally used as levers to raise their wages, which disorganise and sometimes totally paralyse all branches of industry, also suggest to the employer the use of mechanical means for handling his raw material and fuel supplies, and the advisability of accumulating them in large quantities in mechanically equipped stores, thereby making himself independent, for a time at least, in that department of his establishment. A stock of coal, for instance, which would enable an industry to carry on for three months, would, if universally adopted, be a sure remedy against coal strikes.

From the economic standpoint the introduction of machines for the mechanical handling of material is essentially a question of rentability, *i.e.*, whether the labour saved by the machinery justifies the capital outlay for the plant. If sufficient labour is to be had at a low rate, it might be, under efficient supervision, more economical to employ hand labour than to invest large sums in machinery. Such conditions obtain, however, only in new countries, and there only till the standard of living of the natives has been gradually raised through intercourse with, and by the example set by, Europeans. One of the results of cheap labour is therefore the smaller inducement to introduce mechanical handling devices.

The wages of the labourer have so much risen of late, that the substitution of the mechanical conveyor for the man with the wheelbarrow and shovel becomes more lucrative every day. The exaggerated importance attached by the followers of Ruskin to hand labour has passed into the region of obsolete and unworkable theories, and mechanical devices are everywhere regarded as being absolutely essential to the progress of all industries, as the increased competition met with in all branches of manufacture has forced upon capitalists the necessity of economising in every department.

The mechanical handling of grain and seeds is of prior date to that of coal and ore, and the construction of granaries and silo-houses on a large scale has been undertaken and the aid of automatic machinery more or less sought to provide means for handling these materials as far as possible without the assistance of hand labour.

Not till comparatively recent years was the engineer able to render any effective assistance in the handling and automatic conveying and storing of such materials. No branch of engineering, however, has so rapidly developed in modern times as the construction of appliances for conveying, loading, unloading, and storing heavy materials. The movement received greater impetus from the many electric power stations and extensions of gasworks which have marked the industrial history of the past thirty-five years.

The loading and unloading of bulk cargoes in and out of vessels and railway trucks used to be effected entirely by hand. In some of the harbours and docks of Africa, India, South America, in the West India Islands, and also in the Far East, this process is still sometimes in vogue for loading vessels, or has been till within the past few years. This primitive mode of handling material is, however, disappearing to make room for mechanical appliances.

The annexed illustration depicts such an instance during the Russian and Japanese War, and shows the coaling of a battleship at Nagasaki, the "Portsmouth" of Japan. Gangs of 50 to 150 natives, both men and women, used to carry the coal in baskets on their heads to and from the ships, the result of their toil being about 3 to 4 tons of coal per carrier per day.

A coal-heaver in this country, unaided by machinery, and having merely a basket and shovel, can transfer 1 ton of coal per hour from a barge to the bunkers of a vessel lying alongside; if aided by such simple mechanical devices as a steam winch, rope and pulley

block, he can transfer 2 tons per hour, that is to say, nine men filling baskets and three men at the winches, together twelve men, can handle 240 tons in ten hours, which is equal to 2 tons per hour per man; while with a hopper-bottomed collier fitted with conveyors—known as a self-trimming collier—seven men can handle 800 tons per hour, or over 100 tons per man. With one of the latest coal-loading plants, however, installed at the Port of Durban, South Africa, one man can handle 1,000 tons of coal per hour and yet at night can hardly feel that he has done a day's work. What better illustration can we have of the necessity of handling by machinery when labour is short?

Coaling of a Battleship at Nagasaki.

Hand labour was good enough in the days when, according to the earliest records, the first coal was shipped from Newcastle in 1226, and landed at Jacob's Lane, in the Fleet, in London; but since then great changes have taken place.

In 1849 the annual production of coal in this country was 107,427,500 tons, of which 13,053,000 tons were exported as cargo or used for steam navigation. The import of sea-borne coal into London is but a small proportion of the coal handled in the principal coal ports of this country. In 1899 the production was 220,094,781 tons, and the export 55,810,024 tons; while in 1917 the coal production was 248,499,240 tons. Besides coal, an immense bulk of other minerals is handled year by year. According to official returns the mineral produce of the United Kingdom for the year 1919¹ amounted to 275,384,528 tons of raw material, this immense tonnage being made up as follows:—

¹ These are the latest statistics available at the time of publication. (See Preface.)

OUTPUT OF MINERALS FOR 1919

	Tons.	Tons.
Coal - - - - -	...	229,779,517
Iron ore - - - - -	12,254,195	
Lead „ - - - - -	13,868	
Zinc „ - - - - -	6,933	
Tin „ (dressed) - - - - -	5,156	
Bog „ - - - - -	3,045	
Copper ore - - - - -	372	
Manganese ore - - - - -	12,078	
Tungsten „ - - - - -	166	
		12,295,813
Limestone - - - - -	9,537,495	
Chalk - - - - -	2,629,406	
Gypsum - - - - -	220,003	
		12,386,904
Slate - - - - -	164,098	
Clays and Shale - - - - -	7,765,965	
Oil Shale - - - - -	2,763,875	
		10,693,938
Salt, rock - - - - -	90,938	
Salt from brine - - - - -	1,817,142	
Sandstone - - - - -	1,699,853	
Igneous rocks - - - - -	4,387,703	
Gravel and sand - - - - -	2,048,427	
		10,044,063
Alum shale - - - - -	4,848	
Arsenic - - - - -	2,527	
Arsenical pyrites - - - - -	75	
Barium (compounds) - - - - -	60,087	
Bauxite - - - - -	9,221	
Chert, flint, etc. - - - - -	50,082	
Chromite of iron - - - - -	150	
Fluor spar - - - - -	36,860	
Iron pyrites - - - - -	7,336	
Ochre, umber, etc. - - - - -	10,547	
Soapstone - - - - -	688	
Sulphate of Strontia - - - - -	1,872	
		184,293
Total - - - - -		<u>275,384,528</u>

It is obvious that such quantities can only be economically handled by mechanical means.

The quantities given for export coal are by no means the total quantity loaded and unloaded, as all the sea-borne coal that is only shipped from home port to home port must be added ; whilst the former has only to be handled once at the dock, the latter may have to be handled twice or thrice. In addition to the coal shipped, there is a

large bulk which is carried by rail, and should be more or less mechanically loaded or unloaded into or out of trucks.

Not only have these large quantities of minerals to be handled in the course of each year between ships, barges, trucks, and stores, but the immense bulk of our grain and seed imports must be dealt with by mechanical means.

According to Board of Agriculture statistics, the United Kingdom consumed in 1919¹ 13,458,660 tons of cereals, and as the home production only amounted to 6,695,910 tons, the balance of 6,762,750 tons² had to be imported. In addition to this, we imported 1,042,044 tons of seeds, principally for the extraction of oil. This gives the respectable total of 14,500,704 tons of grain and seeds to be handled per annum.

The bulk of the imported cargoes of grain and seeds is carried in large ocean-going steamers for which there is only accommodation in our principal ports. The grain, therefore, is in many instances unloaded from the large vessel into smaller ones which can enter the rivers and canals and deliver the grain to its final destination. This means that the bulk of these cargoes has to be handled twice over.

In the introduction of machinery for the automatic handling of such material, America no doubt took the lead, a step which was largely due to the peculiar conditions of that country, where a saving of labour was at that time perhaps more important than in Europe. It must be admitted, however, that in this country and on the Continent the lead taken by America was quickly followed up, and both here and abroad American methods of mechanically handling such goods have been more or less universally adopted.

Before the war this country was not—as a nation—sufficiently progressive in the adoption of labour-saving devices. Government establishments particularly were most conservative. It was, in those days, very difficult to persuade some branches of the War Office that it was of national importance to handle war material by machinery. They rejected sundry conveyors as unsuitable, experimenting instead on their own in order to discover things which had been known for years to handling engineers. Some of the well-known and long established factories were thus far behind those which sprang up during the early days of the war in the employment of such devices. In the end, however, no applied science, bar chemistry, did so much towards the successful conduct of the war—apart, of course, from the actual fighting—as the application of mechanical handling devices at munition works, transport depots, munition dumps, and even on the actual fighting fronts, for handling the commissariat and the wounded. For instance, it may not be generally known that in the manufacture of shells 10 to 20 per cent. of the total time was expended in the handling from machine to machine, and that the time taken in the production of a 9·2 shell may vary from four hours and thirty-eight minutes to five hours and fifty-one minutes, according to the skill of the worker, but more particularly the efficiency of the handling methods employed. We thus see that handling machines saved more than an hour on but one of the millions of shells produced. Telphers, ropeways, and gravity runways have been employed most extensively for war work. It may also be of interest to state that amongst many other conveyors employed on the Western Front was a 5-mile ropeway, used for handling ammunition boxes at a depot, which was captured by the Germans and worked by them near Cambrai. It was afterwards recaptured by the Canadians and used for forestry work. The Italians made use of ropeways for the conveyance of rations, ammunition, and the wounded up and down the mountains, as also did the Central Powers. Towards the

¹ These are the latest statistics available at the time of publication which are undistorted by the war.

² This includes 1,132,750 tons imported in the form of flour and meal.

end of the war numerous lengths of ropeways, left behind by the retreating Germans, were captured by the Allies.

One of the disadvantages from which this country suffered most at the outbreak of war was the inadequate equipment of her ports with mechanical handling devices, Continental ports, more particularly Dutch and German ones, being better off in that respect. French ports were even worse off, being so poorly equipped that when America came into the war she had to install facilities for the necessary traffic handling at Brest and elsewhere for her own use, an example of which is shown in the accompanying illustration, Fig. 1. Owing to such congestion vessels were sometimes compelled to seek fresh ports for the purpose of unloading and while doing so fell a prey to prowling submarines, being ultimately lost, cargo and all.

•

Fig. 1. Equipment of Brownhoist Wharf Cranes for Unloading Commissariat for the American Army in France. These Cranes span Three Lines of Rails.

In the following chapters mechanical devices will be investigated by means of which the burden of human labour has been lightened, and the scope of the work much increased.

Of all the materials to be handled coal, which is not only a raw material of prime necessity in almost every branch of industry,—notwithstanding the headway being made by oil fuels—but is also a material of considerable intrinsic value, a value which is subject to rapid and sensible depreciation from careless handling, deserves the first place, and no doubt it has been the subject of more careful thought on the part of handling engineers than any other heavy material. These remarks refer more particularly to the loading and unloading of vessels and railway trucks, and the accumulation and reclaiming from stock heaps and overhead bunkers.

It may, however, be observed that the same means of automatically conveying and handling coal are very generally applicable to other heavy substances, such as ores and coke, though no doubt the special nature of the material to be handled must always be taken into account.

The loading of ships with coal is a comparatively simple matter. The railway trucks containing the coal may either be lifted bodily and their contents shot into the ship, or

they may be discharged from the quayside and conveyed into the ship by a conveyor. To prevent depreciation by rough handling, many ingenious forms of discharging apparatus have been invented, which are one and all intended to reduce or break the fall of the material, thus bringing it into the hold of the vessel in as whole and sound a condition as possible. In order to save trimming in the hold, ships have been specially built with a great number of hatchways. Several mechanical trimming devices have also been introduced recently.

An important subject is the service of large boiler-houses and gasworks. Here mechanical means are used for filling and discharging bunkers, bins, or silos, and two essential features in such installations are the automatic feeding of the boilers and retorts, and the removal of the ashes and coke.

Much attention has also been devoted to the coaling of railway engines and the feeding of blast furnaces.

The subject of mechanical handling of material is a very extensive one, and is here divided into—

Appliances which deal with the material CONTINUOUSLY—that is, receive and deliver it in an uninterrupted stream—such plant, for instance, as is suitable for factory yards, coal and other mines, gasworks, power stations, etc., and

Such installations as serve to handle material INTERMITTENTLY and for longer distances, as light railways, ropeways, and telfers, in conjunction with grabs and other unloading devices.

In dealing with machines of the continuous type it will be evident that the material to be handled is evenly distributed over the entire length of the elevator or conveyor; the structure is thus only burdened with a comparatively moderate weight, a fact which permits of a relatively light construction of the mechanism and its supports. For this reason appliances of this type have often a distinct advantage over intermittent handling devices which must lift or convey a concentrated load consisting of the material handled and the receptacle in which it is carried, and necessarily requires machinery and structure of heavier description and of more solid construction.

The greatest drawback of some intermittent handling devices is the time lost in returning the empty receptacle to the feeding point. This refers more particularly to devices which work in a reciprocatory manner.

Most important factors in the choice of machinery for given purposes are general local conditions and the adaptation of the machinery to the space available.

The material should be handled as gently as possible if it be liable to deteriorate through breakage, as in the case of coal, which may easily lose from 5 to 10 per cent. of its value through rough handling, and this consideration is even more urgent in the case of coke, as coke dust is almost worthless.

Installations should be as free from liability to accidents as it is possible to attain, as human lives and valuable property may be lost by accidents and breakdowns.

The Continuous Handling of Material.—The subject of handling material continuously may be classified under three heads:—

1. APPLIANCES FOR LIFTING IN A VERTICAL DIRECTION, OR FROM ONE LEVEL TO ANOTHER, COMMONLY CALLED **BUCKET ELEVATORS**.

2. APPLIANCES FOR MOVING MATERIAL, ESSENTIALLY IN A HORIZONTAL DIRECTION, COMMONLY CALLED **CONVEYORS**.

3. APPLIANCES WHICH COMBINE THE TWO FORMER OBJECTS BY ELEVATING AND CONVEYING THE MATERIAL HORIZONTALLY AT THE SAME TIME. This classification

does not apply to inclined elevators and conveyors, which also virtually elevate and convey at the same time.

Conveyors are subdivided—

Firstly, into appliances consisting of a stationary trough in which the material is conveyed by means of a continuous pushing device ;

Secondly, into appliances with a stationary trough in which the material is conveyed by means of a reciprocating pushing device ;

Thirdly, into appliances in which the trough containing the material moves bodily with the material ; and

Fourthly, into appliances in which the material is conveyed by a semi-stationary reciprocating trough.

Intermittent Handling of Material.—This subject cannot well be classified under distinctive heads ; each type is, therefore, dealt with in a separate chapter.

In the succeeding pages the earlier appliances employed are briefly described, more space being devoted to those which have recently been introduced.

CONTINUOUS HANDLING OF MATERIAL

ELEVATORS, CONVEYORS, AND COMBINATIONS OF THE TWO APPLIANCES

ELEVATORS

A. FOR MATERIAL IN BULK; B. FOR LARGER INDIVIDUAL OBJECTS

CHAPTER II

A.—BUCKET ELEVATORS FOR MATERIAL IN BULK

Introductory.—The most ancient method of elevating material, although it cannot strictly be called an elevator, is none the less of interest; as all the members composing such a machine are present without, however, the mechanical element, it may be termed a human elevator. Fig. 2¹ is a reproduction of a part of an alabaster bas-relief discovered by Sir Henry Layard. It formed part of the wall decorations of the palace of Sennacherib, the Assyrian king who destroyed Babylon in 694 B.C. The illustration is one of a series representing the building of the palace. The men are captives from the city of Balada, and are raising an artificial mound or plateau upon which the palace was erected. The alabaster slab is now in the British Museum.

Bucket elevators in a primitive form have been known and used for a very considerable time, and since their introduction have undergone little alteration except in detail. The term elevator is usually applied to endless belts or chains to which are attached a series of suitably shaped receptacles or buckets. These chains or belts run over two terminal pulleys which are fixed at different levels, the distance from centre to centre of these pulleys being called the length of the elevator.

It is not intended to waste space here by going into details of the construction of the numerous types and patterns of chains and buckets used for elevators, and which are made by specialists as mass production, beyond giving the actual shape of the buckets, as it is obvious that a light chain and buckets of a small gauge will answer for light materials, whilst heavy chains and buckets should be used for specifically heavy, and especially cutting materials.

Elevators are designed to suit special purposes. For instance, grain elevators are always encased in wooden or iron trunks, the head and foot being also of wood or iron. The position of the elevator trunk in this case is nearly always vertical. The support for the buckets consists either of leather or cotton belting, hemp webbing, or india-rubber with cotton insertion. For minerals—coal, coke, cement clinker, and other heavy

¹ From "Engineering of Antiquity," by G. F. Zimmer.

materials—elevators are usually fitted with sprocket wheels and chains which support the buckets. The elevator in the latter case is generally in a slanting position. The buckets are attached to the links of the chain, and intermediate short skidder bars are employed which slide on well-oiled angle-bars on each side. For extra heavy work

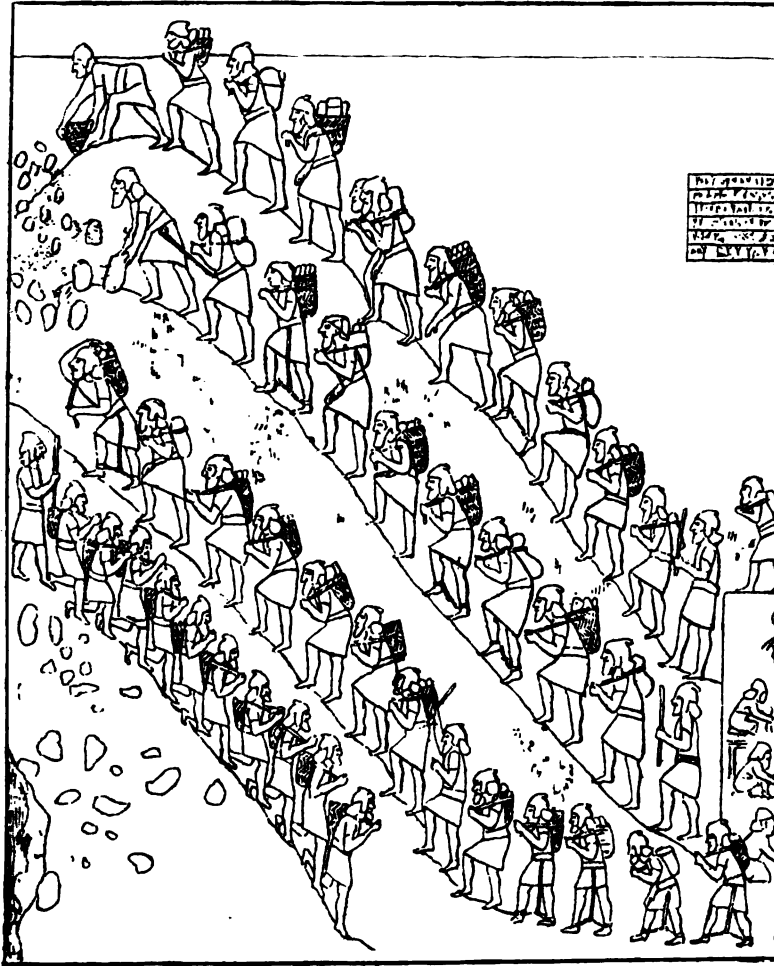


Fig. 2. Human Elevator Constructing a Mound upon which the Palace of King Sennacherib was built.

From a bas-relief of this palace, now at the British Museum.

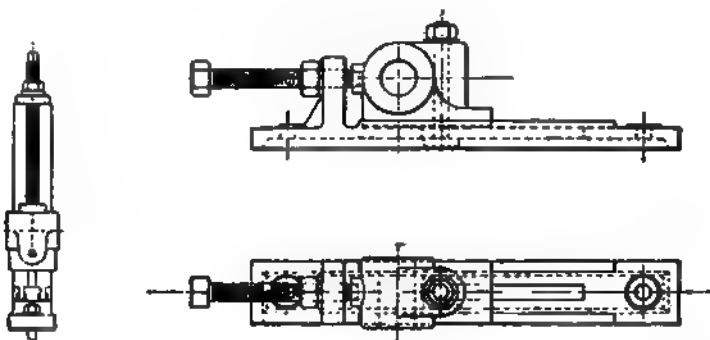
the skidder bars are replaced by rollers. These prevent the buckets and chain from sagging.

Tightening Gears.—Both grain and mineral elevators are generally furnished with tightening gears to keep the belt or chain taut. These are usually arranged at the lower or well end of the elevator, because if placed at the top or delivery end the tightening of the chain or band disturbs the driving arrangements, which should be at the upper terminal. The ordinary tightening gear at the elevator well has this disadvantage, that the space between the bottom of the well and the bucket must vary.

Where grain elevators are concerned this is of little consequence, but in elevators handling coal, minerals, and other material of varying size, it is desirable to keep an even space between the buckets and the bottom of the well to prevent jamming, as shown in Fig. 11. In this case the elevator well is designed to go down with a sprocket wheel when the chain is tightened, and vice versa, whilst the bracket supporting the elevator well remains a fixture. This is only applicable to elevators handling small pieces; for coarser material no elevator wells are used.

There is a third way of tightening elevators without interfering with either the feed or the delivery end, and this is by means of a separate tightening or jockey pulley arranged at some convenient points on their length, in a similar manner to the pulley shown in Fig. 11 (although in this particular instance the pulley is for another purpose).

As a rule, especially with grain elevators, the tightening gear is made as part of the elevator well; but for larger elevators, particularly those which are used for heavy material, the tightening gear is separately mounted on the supporting girders of the elevator framing, and the well is entirely dispensed with. Figs. 3 to 6 show two such tightening gears. Both have an adjustment which will allow of holding the bearing in



Figs. 3 and 4.

Figs. 5 and 6.

Elevator Tightening Gears.

position after tightening. The construction is so simple that it explains itself. The gear shown in Figs. 3 and 4 allows of an adjustment to suit elevators at a variety of inclines. (See also Tightening Gears, Chapter XVI., page 197.)

To Prevent Choking.—The buckets should be made large enough to cope readily with the feed, and at the same time due allowance must be made for the largest pieces to be elevated. In addition to this, the elevator must be fed correctly. For instance, if fed from a large accumulation of material, say from a stock heap or from a bin or hopper, it would not do to feed the elevator by an ordinary spout or shoot.

In such a case the elevator should preferably be fed by a mechanical feeding device, such as an oscillating feed shoot, making between 30 and 60 oscillations per minute, which deposits at each backward and forward stroke a quantity corresponding to the capacity of the elevator. This precaution is, however, only necessary when dealing with minerals of uneven size (see Feeding Devices, pages 223-27), and would not be necessary when handling grain or seeds. The choking, if ordinary spouts are used, is due to one of two primary causes. Either the rush of feed is too great, and is therefore more than the elevator can take up, or else a few large pieces of material have found their way to just above the feed spout and arch it over, thus stopping the feed flowing to the elevator. Feeding devices will obviate both. They will not allow an undue

rush of feed, and will prevent the arching over by keeping the material constantly in motion. These devices may be used not only for feeding from large stock hoppers, but also for equalising the flow of material from smaller hoppers, which are fed intermittently by grabs, etc., or which receive at intervals the contents of trucks or railway wagons, and serve the purpose of paying the material out in a uniform stream, thereby converting an intermittent supply into a continuous one.

The elevator should always be fed on the side on which the buckets ascend, so that the stream of material runs into the elevator buckets, meeting them on their upward journey. This will prevent the material from falling into the elevator well, and does not necessitate the buckets dredging through an accumulation of feed. If elevators are erected at an incline, it is advisable, where possible, to feed them at a point several feet above the well into the up-going strand, as in this case very little will miss the buckets and drop into the well.

Double Chains for Large Elevators.—For elevators of very large capacity two or more strands of chain are sometimes used to support the buckets, but there is a drawback to the employment of multiple strands when using ordinary malleable cast chains, as the different strands are apt to stretch or wear unevenly and throw the buckets out of parallel with each other. It is therefore always best, when possible, to use one chain of sufficient strength, or chains with double links, that is, two links cast together with a web in the middle. These remarks refer only to ordinary malleable cast chains, and not to steel or wrought-iron link chains, which are jointed together by steel bolts through bored holes. This latter kind of chain is always used for elevators of large capacities and for heavy materials, such as coal, and runs over polygon or sprocket wheels.

Position of Elevators and their Speed of Running.—The reason why an elevator should sometimes be vertical and sometimes set in an inclined direction is this. In elevating materials of low specific gravity an elevator can be driven at a much higher speed than the elevator which is handling material of higher specific gravity, as a velocity of the material at the delivery which would not injure grain would break up coal and other heavier and friable products. Moreover, the receiving spouts and shoots would be quickly destroyed by the impact of the material. Elevators in a vertical position are therefore only suitable for specifically light material, and can be run at a circumferential velocity of 250 to 350 ft. per minute. Elevators for heavy material must be either wholly or partially inclined, to give a clean delivery without scattering at the much slower speed of 50 to 160 ft. per minute. At a speed of 180 ft. per minute the centrifugal force which helps fast elevators to give a clean delivery ceases altogether, so that the stuff simply falls out by gravity in slow elevators. It is for these reasons that slow elevators for specifically heavy material require so much larger buckets, chains, etc., than grain elevators of the same bulk capacity.

There is a second reason why it is essential to run an elevator for heavy material up an incline, namely, the fact that it is more easily driven; for part of the load is then borne by the inclined supports instead of the whole weight hanging from the driving gear, as in the vertical elevator. The angle at which to fix an elevator in order to get the most favourable results, without occupying too much space, is 45° to 60° to the horizontal.

The speed of elevators, which are fixed in a perpendicular position for dealing with grain, etc., depends upon the diameter of the pulley, *i.e.*, the pulley on which the band which carries the buckets is running, because such an elevator, in order to deliver perfectly, must throw the grain a certain distance, which is equal to the radius of the

pulley plus about 1 ft., in order to clear the preceding buckets and to reach the discharge spout, except in cases where special buckets—referred to later—are used. The elevator buckets generally begin to discharge when in the highest position on top of the pulley. To effect perfect discharge from a perpendicular elevator the centrifugal force must be sufficient to overcome the gravity of the material, so that for a specifically heavy material it is necessary to have a greater centrifugal force, *i.e.*, higher speed of elevator than for a specifically lighter material, as no matter with what velocity a body may be thrown off tangentially from the elevator pulley, the moment it is free from its support the attraction of the earth asserts itself and causes the body to eventually fall. If the direction of the material is horizontal, as is the case in the delivery from a vertical elevator, the attraction of the earth causes the body to move in a parabolic curve, and the heavier the body, the more will its path deviate from the horizontal at every instance (see Fig. 7). A light body at a given linear velocity will proceed in an approximately horizontal line for a longer distance than a heavy body, as the earth's attraction is more or less counteracted by the friction of the atmosphere.

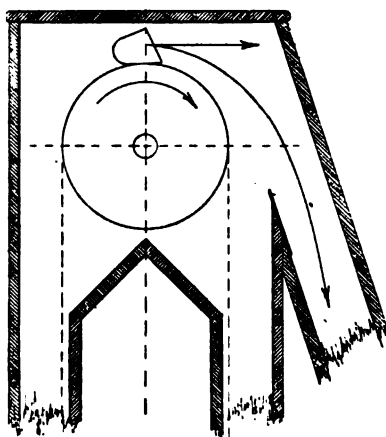


Fig. 7. Diagram showing Discharge of Elevator Bucket.

The centrifugal force of pulleys revolving at the same speed is in direct proportion to the diameter of the pulleys. For example, in a 2-ft. pulley it will be twice what it is in a pulley 1 ft. in diameter running at the same speed when the speed of an elevator pulley of a given diameter is increased, the centrifugal force increases in proportion to the square of its velocity; consequently the centrifugal force of a pulley 2 ft. in diameter, running at 50 revs. per minute, will be four times the centrifugal force of a pulley of the same diameter running at only 25 revs. per minute. This indicates clearly that in the case of grain elevators it is quite inaccurate to estimate the number of revolutions of the elevator pulley by a fixed belt speed for pulleys of all sizes, which is a mode of calculation too frequently adopted.

In addition to what has been mentioned concerning clean delivery at the top terminal of elevators, the shape of the elevator buckets—correctly chosen for each material—determines also to some extent the useful effect of the theoretical capacity of elevators; for this depends upon the amount spilled on the up-going strand, and that spilled at the top terminal between the buckets and the delivery shoot. If a shallow bucket, intended for soft and clinging materials, is employed for sharp or lively materials, it will fill itself with more than it can carry, and some will fall back at the point where the elevator band begins to turn over the top terminal pulley. A soft and clinging material will fill such buckets equally full, or perhaps even more so, but owing to its nature it will not spill out. The efficiency of elevators finally depends upon the regularity of the feed, so that the buckets are not sometimes overloaded and sometimes only partly full. This can be regulated by a feeding device, as described on pages 223-27.

A grain elevator which has come under the special notice of the author is one in a large Cardiff flour mill. The pulleys are 24 in. diameter by 18 in. on face, and the speed is 60 revs. The buckets are 15 in. wide, project $6\frac{1}{4}$ in. from the band, and are 17 in. pitch. The belt speed is 375 ft. per minute, and 265 buckets pass

per minute or 15,900 per hour. Each bucket holds 10 lb. of wheat, so that the theoretical capacity of this elevator is 159,000 lb., or 71 tons per hour. The actual average capacity is 60 tons of wheat per hour, equal to an efficiency of 85 per cent.

SPEED AND CAPACITY OF GRAIN ELEVATORS OF DIFFERENT SIZE

Diameter of Pulley.	Width of Pulley.	Size of Buckets.	Pitch of Buckets.	Revolutions per Minute.	Speed of Belt per Minute in Feet.	Capacity in Tons and Bushels per Hour.	
Inches.	Inches.	Inches.	Inches.			Tons.	Bushels.
18	11	9 × 4	17	58 to 62	280	13½	500
21	13	11 × 4	17	52 „ 56	300	27	1,000
24	15	13 × 5	18	48 „ 52	310	40	1,500
27	17	15 × 5	18	44 „ 48	320	45	2,000
30	19	17 × 5	18	40 „ 44	330	70	2,500
33	21	19 × 6	19	38 „ 42	340	81	3,000
36	23	21 × 6	19	36 „ 40	350	95	3,500
42	25	23 × 7	20	32 „ 34	360	108	4,000
48	26	24 × 8	21	31 „ 33	400	140	5,000
60	26	24 × 8	21	31 „ 33	500	170	6,250
72	26	24 × 8	21	31 „ 33	600	203	7,500

Probably the largest grain elevator in the United Kingdom is that at the Manchester end of the Manchester Ship Canal, which has a handling capacity of 350 tons per hour.

The following table of capacities of elevators running at different speeds was given by Mr P. W. Britton in his paper on the "Transprot and Storage of Grain,"¹ the buckets being 12 in. apart.

Size of Buckets.				Number of Bushels Raised per Hour.		
				Speed = 200 Feet per Minute.	Speed = 300 Feet per Minute.	Speed = 500 Feet per Minute.
6 inches by 4 inches	-	-	-	275	412	687
8 „ 5 „	-	-	-	600	900	1,500
10 „ 5½ „	-	-	-	850	1,275	2,125
12 „ 6 „	-	-	-	1,300	1,950	3,250
14 „ 6 „	-	-	-	1,600	2,400	4,000
20 „ 6 „	-	-	-	2,275	3,412	5,687

If placed at any further distance apart, the capacity would diminish in direct proportion, so that with elevator buckets spaced 2 ft. apart, the capacity of the respective elevators would only be half that given in the table.

Unless buckets are of special construction, such as those shown in Fig. 15, it is advisable to keep a space between them not less than that occupied by one bucket, so that an elevator thus fitted with ordinary buckets would be of half the capacity of that of the elevator shown in Fig. 15, provided the buckets themselves were in both cases of the same capacity.

¹ *Proceedings Inst. C.E.*, vol. cxxvi., 1895-96.

In cases where it is necessary to employ large top terminal pulleys (3 ft. and over) in order to obtain delivery of a desired quantity in a given time, the bottom terminal pulley may be of smaller size, in which case the elevator legs are not parallel, but at an angle with the axis of the elevator. Fig. 8 illustrates the usual form of grain elevator.

Speed and Capacity of Mineral Elevators.—As regards data for mineral elevators, it is exceedingly difficult to tabulate such information, as the speed and consequently the capacity of such elevators vary greatly with the nature of the material

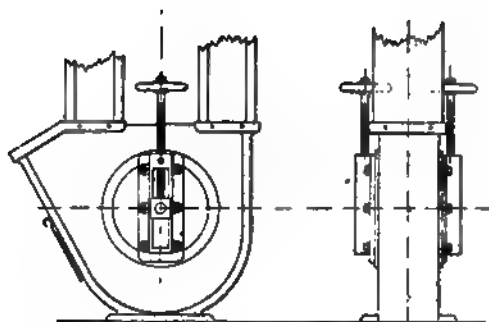


Fig. 8. Usual Form of Grain Elevator.

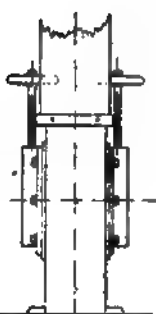


Fig. 9. Top of Mineral Elevator.

to be elevated, whether hard, tough, or friable. While it is usual to run coal elevators 90 to 130 ft. per minute, according to the friability of the coal, coke elevators run only at 50 to 90 ft. per minute; while, on the other hand, minerals which do not deteriorate through breakage may be elevated at the rate of 120 to 160 ft. per minute.

The capacity of such elevators depends of course on the speed of travel and on the size and pitch of the buckets. The following table gives a few particulars of the speed and capacity of coal elevators:—

Width of Buckets.	Pitch.	Speed of Travel.	Delivery.
Inches.	Inches.	Feet per Minute.	Tons per Hour.
12	18	120	20
18	18	120	40
24	18	120	60

Figs. 9 and 10 show the most common form of mineral elevator, Fig. 9 representing the top and Fig. 10 the lower part of the same elevator.

Devices to Ensure Clean Delivery from Slow-Running Elevators.—

Fig. 11 shows a form sometimes adopted for slow-running elevators, and when the material is of a sluggish nature and not, therefore, discharged readily out of the buckets, or where local conditions, such as want of space, etc., make it necessary to fix the elevator at a steeper incline than 60° . It is apparent that such an elevator as is shown in Fig. 11 must have double strands of chain placed on either side of the buckets,

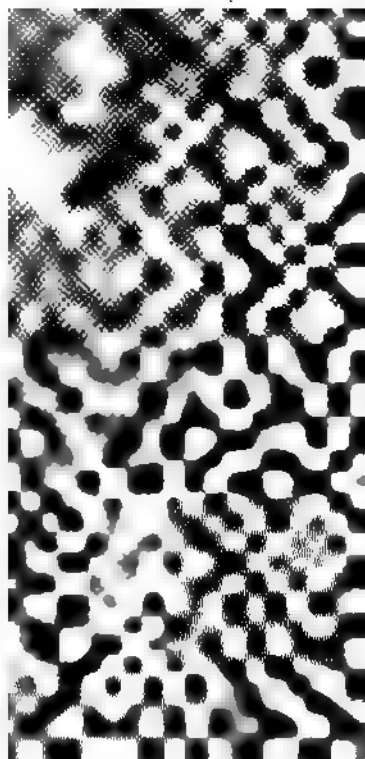


Fig. 10. Well of Mineral Elevator.

Fig. 11. "Vertical Dump" Elevator which Facilitates Delivery.

so that the guide wheels which curve the chain may not foul the buckets. Similar elevators are, however, made with single strands of chain with skidder bars which slide round two angle-bar curves instead of the guide pulleys. This construction is, however, only advisable for small installations.

The same idea is further developed by the adoption of two upper terminals, so as to give the elevator chain a horizontal run between these two terminals (see Fig. 12). A push-plate conveyor is shown as an addition to the elevator, which gives a good idea of the delivery.

The Link Belt Company have adopted an ingenious device to get a clean delivery from a slow-running elevator in a vertical position. It consists of a series of wrought-

iron shoots fixed to the top terminal sprocket wheel (see Fig. 13).¹ These shoots precede each bucket in turn at the point of delivery, and lead the material to the

Fig. 12. Elevator with Two Upper Terminals.

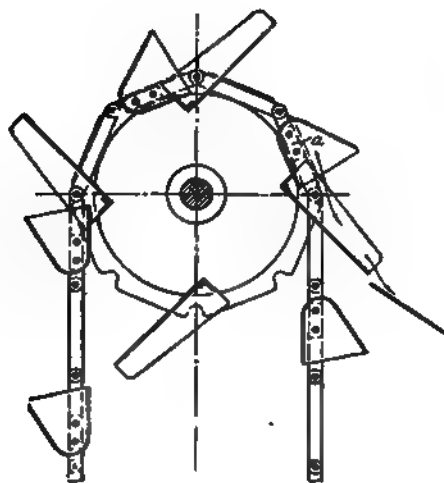


Fig. 13. Top Terminal of Elevator Fitted with Delivery Shoots.

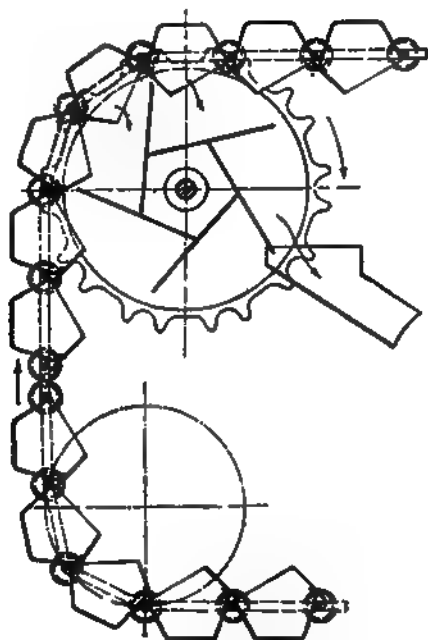


Fig. 14. Elevator with Delivery Shoots between the Top Terminals.

outlet of the elevator. This construction necessitates a pair of endless chains, and the pitch between the buckets must be sufficient to clear the revolving shoots.

¹ Hanfstengel, "Die Forderung von Massengutern."

An elevator with one or more upper terminals and two lower terminals is shown in Fig. 14. In addition to special delivery facilities, it has the peculiar attribute of being capable of conveying horizontally between the two lower terminals, but whether it has one or two top terminals it can only deliver at that point where the chain of buckets traverse the first top terminal. The delivery is unlike that of other elevators, being towards the terminal instead of away from it. In order, therefore, to get a clear delivery the top sprockets are fitted with five plates, filling the space between the two sprocket wheels, and thereby forming revolving delivery shoots, each of which receives the contents of two buckets and leads the material into the delivery shoot proper.

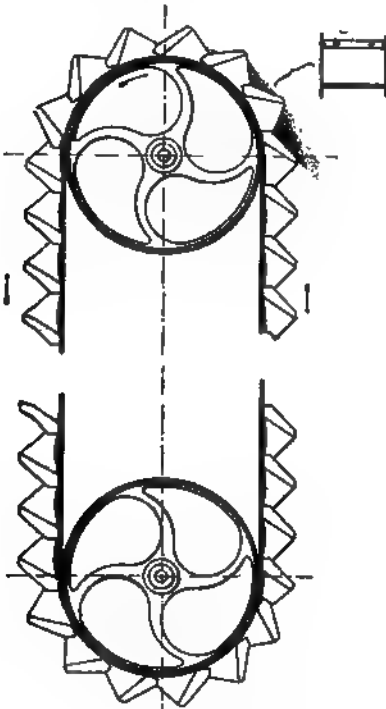


Fig. 15. Continuous Bucket Elevator for Grain.

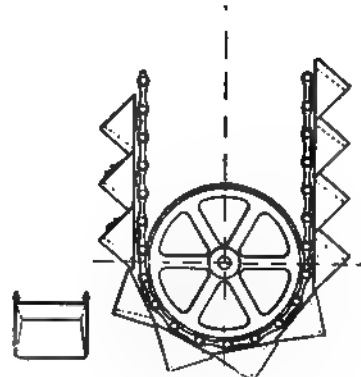


Fig. 16. Continuous Bucket Elevator for Minerals.

Continuous Bucket Elevators.—A very economical form of elevator is one fitted with a continuous chain of buckets. This kind is naturally of a much larger capacity than an ordinary elevator of the same dimensions. It takes and delivers its load with more uniformity, and as the buckets need not plough intermittently through the contents of the elevator well, smoother running is secured. Fig. 15 shows such an elevator for grain, and Fig. 16 for minerals.

The table on the next page gives dimensions of continuous elevator buckets for grain and their capacities in tons per hour at varying speeds.

Elevators for Coke.—The buckets used for coke elevators should be of malleable castings with strengthened lips. They should have skidder bars rather than rollers fixed to the axles, running on the angle iron forming the framework of the elevator on the upward and downward paths. The buckets should also be placed nearer each other

than usual, with the intervening space covered by a light plate, so as to keep all dust from the links and other moving parts.

The shape of the buckets and the angle of the elevator should be so arranged as to give a clean discharge without further devices. The capacity of the elevator must be quite equal to what the conveyor feeding it can ever bring to it, to suit the conditions of discharging from the retorts, which might be almost continuous or very intermittent.

Width of Bucket.	Projections of Bucket.	Speed of Elevator Belt in Feet per Minute.								
		250	300	350	400	450	500	550	600	650
Inches.	Inches.									
4	4	10	12	14	16	18	20	22	24	26
	5	15	17	19	21	23	25	27	29	31
	6	20	22	24	26	28	30	32	34	36
6	4	15	18	21	24	27	30	33	36	39
	5	22½	25½	28½	31½	34½	37½	40½	43½	46½
	6	30	33	36	39	42	45	48	51	54
8	4	20	24	28	32	36	40	44	48	52
	5	30	34	38	42	46	50	54	58	62
	6	40	44	48	52	56	60	64	68	72
10	4	25	30	35	40	45	50	55	60	65
	5	37½	42½	47½	52½	57½	62½	67½	72½	77½
	6	50	55	60	65	70	75	80	85	90
12	4	30	36	42	48	54	60	66	72	78
	5	45	51	57	63	69	75	81	87	93
	6	60	66	72	78	84	90	96	102	108
18	4	45	54	63	72	81	90	99	108	117
	5	67½	76½	85½	94½	103½	112½	121½	130½	139½
	6	90	99	108	117	126	135	144	153	162
24	4	60	72	84	96	108	120	132	144	156
	5	90	102	114	126	138	150	162	174	186
	6	120	132	144	156	168	180	192	204	216
30	4	75	90	105	120	135	150	165	180	195
	5	112½	127½	141½	157½	172½	187½	202½	217½	232½
	6	150	165	180	195	210	225	240	255	270

General Remarks Concerning Elevators for Grain and other Light Materials.—The driving spindle of the upper terminal should be sufficiently strong to support the weight of the elevator itself as well as the load to be conveyed; the pulley and spindle at the lower terminal are merely guides to keep the belt taut and in the proper position. The elevator foot should be fed at a point not lower than the centre of the pulley, while the discharge at the elevator top should not be higher than the level of the under side of the internal pulley. If the delivery spout be placed higher than this, some of the material will miss the spout and drop into the elevator well, causing a draught of air and an overloading of the elevator, with consequent loss of power, as in such a case a proportion of the material will be carried round and round. The draught of air caused by the particles falling into the elevator well is perhaps of

small consequence when dealing with whole grain, but when elevating flour or finer light material this draught of air is most objectionable, as the dust blows out through all the crevices of the elevator casing, and if any door in the elevator is opened a blast of dust will issue from the opening. If, however, the discharge spout be placed about level with, or, better, a few inches below the under side of the pulley, the discharge will be a perfect one, provided the elevator is running at the correct speed, and the buckets of proper form.

Usually these elevators are cased in a wooden box or pair of boxes or trunks which enclose the elevator legs. A space of $1\frac{1}{2}$ to 2 in. should be allowed between the buckets and the trunk in order to obviate any possibility of the buckets touching the trunk;

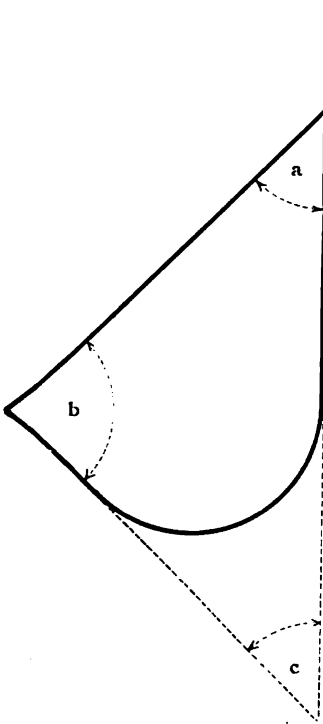


Fig. 17. Bucket for Soft Material.

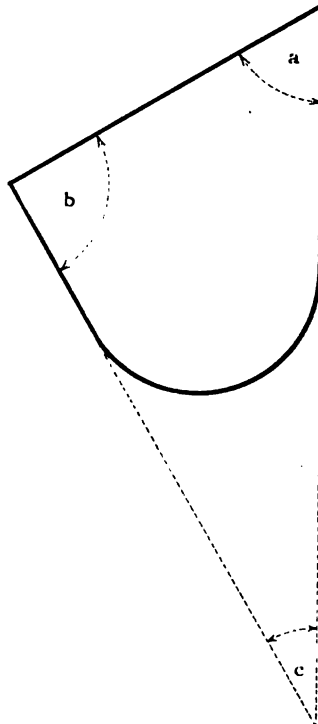


Fig. 18. Bucket for Granular Material.

and further, if the buckets are fitting too close, they are also apt to act as a fan and create a draught, which means dust.

The elevator top which covers the pulley, and which also carries the bearings for the top spindle, may be made either of wood or iron. For ordinary use in flour mills and other factories dealing with light material wood is preferable, as it is easier to attach to the woodwork of the roof or the floor of the building. Iron elevator tops are used in cases where the trunking is also of iron, in order that the elevator may be fireproof. This particularly applies to the wheat-cleaning department of flour mills, to provender mills, or to fireproof factory buildings.

It is advisable to vary the shape of the buckets for the different products they have to handle. A shallow bucket is best for soft and clinging material such as flour, cement, fine or moist sugar, etc., whilst for harder material, such as cereals, etc., a deeper bucket

will be found preferable. The buckets often met with in older flour mills are of such a shape as to make a proper discharge of their contents well-nigh impossible.

Figs. 17 and 18 show two elevator buckets, the former for soft and clinging material, and the latter for more granular material. The former will be found to fill easily and discharge freely such material as flour, etc. A bucket such as is shown in Fig. 18, if used for soft material, would in many cases not fill completely, but would only allow a heap of stuff to rest on the top, leaving a hollow in the lower portion of the bucket; on ascending, the material frequently drops down to the bottom of the bucket, and when it reaches the discharge spout it will not empty in time to fall into the discharge shoot, consequently some of its load will miss the spout and fall down the elevator trunk. In the bucket shown in Fig. 17, the angles $a' b c$ should be 45° , 90° , and 45° respectively; whilst in Fig. 18 they should be 60° , 90° , and 30° . The buckets should be made of sheet iron or steel, and riveted or soldered together; the most modern and best buckets are, however, stamped out in one piece of mild steel. The attachment of the buckets to the elevator band is best effected by bolts with mushroom-shaped heads. Clips, which were formerly used for this purpose, lack strength and are liable to break.

In selecting an elevator it is well to allow a liberal margin in its capacity, unless an automatic feeding device is used.

In the following table will be found suitable sizes for flour-mill elevators, with other useful information:—

Size No.	Diameter of Pulley.	Width.	Revolutions per Minute.	Bucket.			Pitch of Bucket.	Capacity in Bushels per Hour.
				A. Length.	B. Width.	C. Depth.		
	Inches.	Inches.		Inches.	Inches.	Inches.	Inches.	
1	9	5	80	$3\frac{1}{2}$	$2\frac{1}{2}$	2	12	25
2	12	6	75	$4\frac{1}{2}$	3	$2\frac{1}{2}$	12	40
3	15	7	60	$5\frac{1}{2}$	$3\frac{1}{2}$	3	15	90
4	18	8	55	$6\frac{1}{2}$	4	$3\frac{1}{2}$	15	145
5	21	9	50	$7\frac{1}{2}$	$4\frac{1}{2}$	4	18	200
6	24	10	45	$8\frac{1}{2}$	5	$4\frac{1}{2}$	18	400

As the different products in a flour mill vary greatly in specific gravity, a further table is appended in which is given in hundredweights the capacity of different sized elevators when working on different products.

The numbers of elevators given in the top row correspond with the dimensions and particulars given in the previous table. The last four lines of the table refer to the products of the breaks of a flour mill, and the weights are based on a sample of wheat weighing 60 lb. to the bushel. Different break products are marked 1, 2, 3, 4, and refer to the break meal as it comes from the break roller mills and enters the elevators. The weights of the various materials per bushel have been carefully taken by the author, and can be accepted as reliable.

In these two tables the speeds given for different elevators are good average speeds for handling most materials in a flour mill. When treating semolina and other comparatively heavy and granular materials, as well as in the handling of wheat, an increase of 10 per cent. is admissible; while, on the other hand, with flour and very fine

material a reduction of 10 per cent. on the speeds is to be recommended. All elevators will work fairly well at a small margin on either side of the correct speed.

Elevators handling material of a lighter nature should not have the buckets as close together as in the case of heavy material, if running at the same speed. In elevators for soft material the delivery spout should also be placed at a lower point, as the lighter material is necessarily slower in clearing the buckets, and with buckets too close together a portion of the material will fall on to the back of the preceding bucket instead of passing into the outlet spout.

CAPACITY OF ELEVATORS, WITH VARIOUS FOOD-STUFFS AND INTERMEDIATE PRODUCTS OF FLOUR MILLS, IN HUNDREDWEIGHTS PER HOUR

Size of Elevator. (See previous Table.)	1	2	3	4	5	6
Wheat - - - - -	15	24	54	87	120	240
Barley - - - - -	12	20	45	72	100	200
Oats - - - - -	10	16	36	58	80	160
Maize - - - - -	15	24	54	87	120	240
Malt - - - - -	10	16	36	58	80	160
Beans or peas - - - - -	16	26	58	94	130	260
Wheat meal or barley meal - - - - -	10	16	36	58	80	160
Oatmeal - - - - -	19	15	34	55	76	152
Semolina - - - - -	12	20	45	72	100	200
Middlings - - - - -	11	18	40	65	90	180
Flour - - - - -	14	22	50	81	112	224
Fine } pollard	5	7	16	26	36	72
Coarse } or sharps	14	6	14	22	31	61
Chop - - - - -	12	19	42	68	95	190
Bran - - - - -	3	5	11	17	24	48
First break - - - - -	11	18	40	65	90	180
Second break - - - - -	9	14	31	51	70	140
Third break - - - - -	5	7	16	26	36	72
Fourth break - - - - -	4	6	14	22	36	62

If elevators are too small for their load the buckets will be too full, and will commence to spill as soon as they begin to turn over the upper terminal. Flanged pulleys used to be employed for elevators, but they have been generally superseded by ordinary pulleys well rounded on the face. It is most essential that doors should be provided on enclosed elevators for the purpose of examining the elevator top and well. At the former point it will be possible to determine if the delivery is a perfect one, and at the latter to free the elevator easily in the event of a choke. There should also be doors in the elevator legs, preferably on each floor through which the elevator passes if erected in a factory building. At some point in the elevator legs there should be a large door in front as well as at the back of the trunk, preferably near the elevator well. These doors should not be less than 3 ft. in length, and are for the purpose of giving access to the elevator band to allow of shortening it, should this become necessary.

To facilitate tightening, the two ends of the webbing are bound with leather strips about 3 in. wide, and to one end are riveted a pair of straps each some 3 ft. long, and to the other end a corresponding pair of buckles. Whenever the webbing becomes slack it is only necessary to bring this joint to the above-mentioned door and pull up first one and then the other of these straps till the required tension is obtained. Elevator bands

for flour mills and granaries are best made of good textile material, preferably stout cotton webbing. Leather is not advisable, as it never runs as true as a woven band.

The elevator top, if of wood, should always be made in two halves, so that the spindle and pulley can be readily removed for repair if necessary, without dismantling

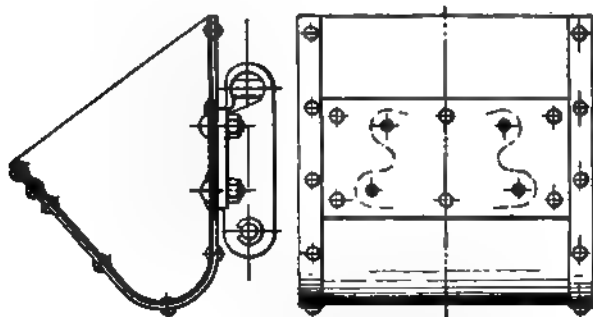


Fig. 19. Riveted Steel Elevator Bucket.

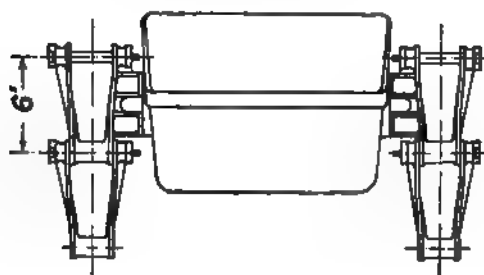


Fig. 20. Double Strand Chain and Bucket.

Figs. 22 and 23. Buckets with Skidder and Roller Supports.

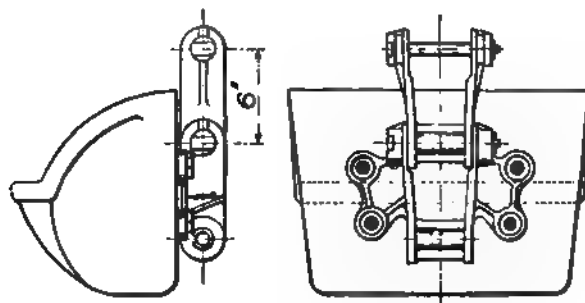


Fig. 21. Malleable-Iron Bucket and Chain.

the elevator. The top and bottom spindles must be perfectly level, or the belt will run continually to one side—a fault that is often not discovered until the edges of the webbing begin to fray out. In erecting flour-mill elevators the holes in the floor should be sufficiently large for the elevator trunks to pass through freely, they should not be fixed to the floor, but held in their correct position by wooden fillets, so that should the

floor spring under an accumulation of sacks the weight will not be on the elevator legs, nor will the latter be affected by the vibration of the floor.

Iron elevator trunks are often used in fireproof buildings. A very neat way of

Fig. 24. Completely Enclosed Chain and Bucket Elevator : Babcock & Wilcox's Standard Type.

making them is to use four pieces of sheet iron, the edges of which are slightly bent, while a small pipe open on one side is pushed over these edges in order to fasten them together. If the trunks are made of wood, the point where two boards join should be fitted with iron tongues in order to prevent leakage of dust.

The best and safest plan is to drive each elevator by a separate pulley. Not more

than two should be driven together by the same belt. Frequently a number of elevators are placed in a line, and one driving shaft runs through and drives the whole of the elevators. There are several reasons against this practice. In the first instance, it would be necessary that all the elevators should deliver in the same direction, which may be inconvenient. This difficulty can, however, be overcome by driving the elevator which should deliver on the opposite side by gearing from the shaft passing through the rest of the elevators, making those which ought to deliver in the opposite direction somewhat shorter or longer, in order to make them terminate either under or above this elevator shaft. There are, however, other objections to driving a number of elevators in a line by one shaft. If one of the elevators should choke, the accident is not so likely to be discovered as in the case of a number of elevators driven singly, for whereas in the latter case the driving belt would come off as soon as the choke took place, in the former the main belt driving the line of elevators would probably, being much stronger, remain in its place, with this result, that the elevator pulley would continue to revolve against the elevator band, which would be held stationary through the accumulation of material. This has been the cause of fires in flour mills, as the friction between the pulley and the band would be sufficient to cause the latter to ignite. The only advantage of having the elevators in one line and driven by one shaft is the saving of expense, and on that account this practice is too often followed, but to drive elevators singly or in pairs is therefore far preferable.

Elevator Buckets for Minerals.—In Figs. 19 to 23 a variety of elevator buckets for minerals are shown, with their chains. They include buckets built up of steel plates as well as malleable cast buckets and such as are stamped out of one piece of pressed steel. Single and double chain examples are represented, as well as the necessary supports for inclined elevators, in the shape of skidder bars and roller supports, both running on renewable, running strips, in the former case, well greased.

An Elevator of the Fully Enclosed Type is shown in Fig. 24. Both strands of the chain of buckets are supported by skidder bars or rollers on angle paths on their upward and downward journey.

Gear Drives for Elevators.—For very large elevators, especially in cases where the available space does not admit of the internal elevator pulleys (sprocket or polygon wheels) being of large diameter, spur or bevel wheels having a ratio of 1 : 2 to 2 : 3 should be employed together with a suitable countershaft.

Power Required for Elevators.—This depends, of course, on the height of the elevator and on the weight to be lifted, but for practical purposes not less than twice the theoretical H.P. should be allowed.

Archimedean Screw Elevators.—These are rarely used, in which case the screw or worm fits fairly tightly into a cylindrical receptacle. Such elevators must be driven 25 to 50 per cent. faster when used for elevating than when used for conveying on the level.

There is no special feature about this particular type of elevator beyond that which will be found under the head of worm conveyors, with the exception that the worm must be of the continuous type, and that the pitch must not be more than half the diameter of the worm. Such elevators can be driven from top or bottom by bevel gear, the latter being the more general arrangement. Such a driving gear is shown in Fig. 25. The upright worm is erected within a receiving hopper, and the material is admitted from the hopper to the worm by two or more inlets.

Spouts and Shoots.—The spouts and shoots which receive the feed from elevators in immediate proximity to the latter, should always be made of stout wrought iron, or

better still, cast iron. For smaller grain elevators, wood, with a sheet-iron lining, will be found sufficient. It is surprising how quickly even cast-iron shoots are worn through by the constant impact of the grain, not to mention heavier and harder substances. A sheet of india-rubber about $\frac{1}{2}$ in. thick secured to the point of impact will last longer than a cast-iron plate of the same thickness. The shoots themselves should be at an incline of say 5 to 10 per cent. greater than the angle of repose of the materials handled.¹

Automatic Feeding Devices for Elevators.—If the material arrives in intermittent charges, and if its subsequent progress is to be continuous by elevator or conveyor, the supply must be changed from an intermittent to a continuous one, for which purpose an automatic feeding device is employed. Too rapid a heaping up of material may lead to chokes, besides causing an unfair strain which might lead to breakages and an undue consumption of power. If the material be delivered from railway or contractors' trucks, ropeway skips, or grabs, the load should be deposited in a hopper (with an adjustable outlet or gate) sufficiently large to hold one charge of the material to be conveyed. The feed to the succeeding elevator or conveyor can thus be regulated in such a way that the hopper pays out its contents at the rate at which the elevator or conveyor can take them, while the truck or grab brings the next load.

One effective device is an inclined table which slides backwards and forwards under the opening of the hopper and allows a certain quantity to leave the hopper at each stroke, which quantity can be adjusted by opening or closing a vertical slide or gate in the side of the hopper. A good plan frequently adopted in gasworks is to fit under the hopper a pair of break rollers which reduce the size of the coal so that it can be more easily handled by the succeeding elevators and conveyors; but even in such cases the feeding devices here mentioned should be used, as the work of a breaker will always improve in proportion to the uniformity of its feed.

Fig. 25. Driving Gear for Worm Elevator.

Quite a number of feeding devices have been introduced which dole out the right quantity for each elevator bucket, one of which, shown in Fig. 26, effectually solves the problem. It provides an intermittent feed of just sufficient bulk to fill each bucket, doled out at the exact moment that the bucket is in the right position to receive it. The most obvious advantage of this device is the deletion of the elevator well with its inherent disadvantages. The feeding device thus synchronised with the motion of the buckets consists of a reciprocating feed table *b*, attached to the base of feed hopper *a*. The former moves on four rollers on two angle-iron paths. Feed gate *l* is adjustable to permit the exact amount to be paid out with each stroke. Levers *c*, *d*, and *e* produce the reciprocating motion, actuated by a crank disc *k*, with adjustable stroke. Driving power is taken from the lower terminal spindle. With an elevator such as shown, where, with every revolution of the spindle, two buckets pass the feeding point, it is necessary, in order to synchronise the feeding table with the progress of the buckets, that the countershaft which actuates the reciprocating motion should be geared 1 : 2. This

¹ For inclines of shoots see Conveying by Gravity.

proportion varies with the number of sides of the terminal when polygonal, and with the number of buckets which pass with every revolution. With a similar chain, for instance, and hexagonal terminal, the proportion of the wheels, whether gear or chain driven, would have to be 1:3. Such a device would work satisfactorily at the base of a coal pocket or in conjunction with an under-rail hopper, in which the coal is received from railway trucks.

A feeding device, which is known as the Mitchell Rotary Feeder, consists of a revolving disc concentric with a stationary feed hopper, from which an adjustable plough withdraws the feed into the elevator in a way to meet the ascending buckets; a chain drive and pair of bevel gears operate the feeding device from the lower terminal in a

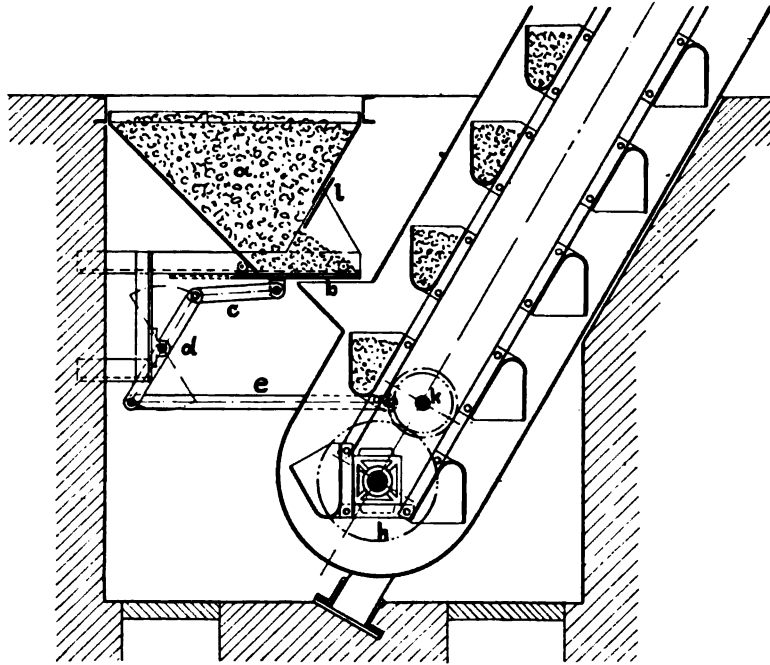


Fig. 26. Synchronised Feeding Device for Bucket Elevator.

satisfactory manner. The apparatus is, moreover, inexpensive, easily and quickly adjusted, and always open to view.

Fig. 27 shows a mechanical feeding device for elevators in which a short Zimmer conveyor is used, into which the coal falls through a receiving hopper above. In this case the hopper is fed intermittently by narrow gauge trucks. By the use of a slide or gate the quantity of material it is desired to convey can be regulated. Feeding devices can of course be used equally well for feeding other kinds of conveying appliances. It is always well, where possible, to drive the feeding device from the machines which are to be fed, so that when the elevator or conveyor is at a standstill the feed may also automatically cease. This is of great importance, for if arranged otherwise the conveying machine at its feed end would on starting be so full of material, that in attempting to start it the driving band would most likely come off, or if driven by a chain, breakdowns might take place. The installation shown in Fig. 27 represents the feeding device

driven from the lower terminal. This is all right as long as the elevator is a chain elevator, so that its bottom terminal must revolve with the elevator; but such an arrangement would not be suitable with elevators in which the buckets are fixed to a band, as these sometimes slip.

Another device, which is illustrated in Fig. 28, consists of a small trough suspended under the delivery end of a bin by four mild steel hangers. This shoot is put into



Fig. 27. Mechanical Feeding Device for Elevators.

oscillating motion by levers attached to one or two of the suspended arms. As the trough swings backward the coal it may contain will not slide backwards with the shoot, but will fall forward through a spout on to the conveyor or elevator to be fed. At the forward movement of the shoot the coal from the bin above will slide down into the space that is now left vacant by the pieces that have moved forward, so that the material is gradually

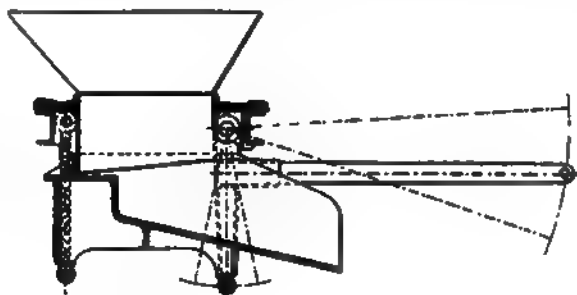


Fig. 28. Oscillating Feeding Device for Elevators.

and evenly deposited with each backward and forward motion. This shoot is put in action by a crank and connecting rod in such a way that the throw can be altered at will, and the feed regulated to a nicety. Similar appliances are used in which the shoots are supported on four small rollers moving backward and forward on suitable rails. In such cases the shoot is generally level instead of being at an incline. The speed at which such feeding devices are operated depends to a great extent on the size of the material. If small, the feeding device should take only a little at each movement and repeat the

movements frequently; but if the material is large, the movements should be fewer, and a heavier feed should be allowed for each movement. (For other Feeding Devices see Chapter XVIII., pages 223-27.)

An interesting form of elevator,¹ in which both top and bottom terminals are combined into one wheel, the lower part receiving whilst the upper or highest point gives delivery, is illustrated in Figs. 29 and 30. It is used for coaling railway engines, and is installed by the Hungarian Südbahn (Southern Railway) at Nagykanizsa. The apparatus is portable, and consists of a wheel 5 metres, say 16 ft., in diameter, which revolves slowly in the direction of the arrow on its spindle. The boss is long and the spokes are on one side only, to leave the interior of the wheel accessible for the inlet and outlet as well as for the shield α . The rim of the wheel is made of channel

Figs. 29 and 30. Coal Elevator in which Both Terminals are Combined into One.

section \square closed at the outside and open towards the middle. This rim is divided into sixteen compartments which represent the elevator buckets.

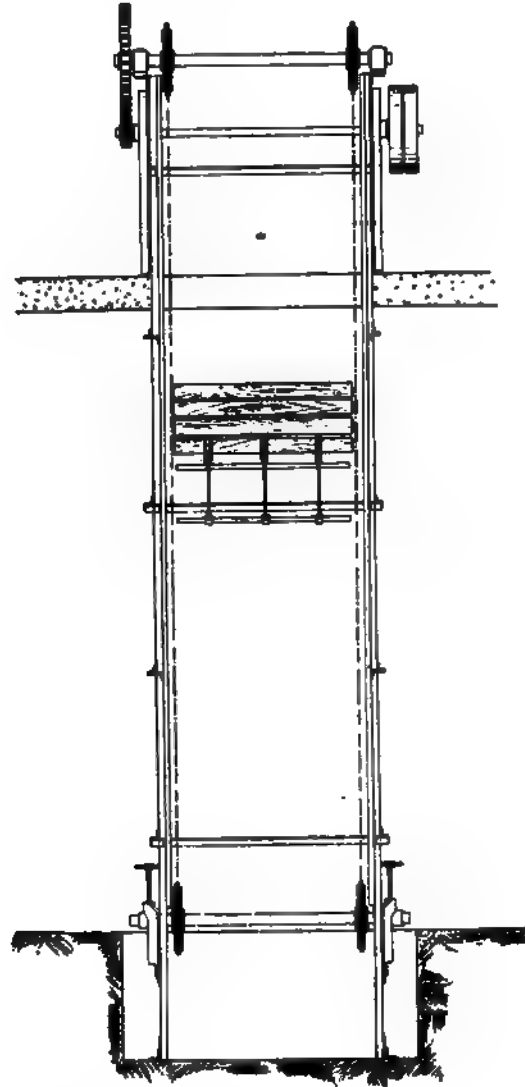
A portion of the illustration is in section, and shows the stationary shield α which closes the channel at the inside for that portion where the coal is conveyed more or less on it. It will be understood that when the coal is fed by wheelbarrows at the lowest point, it is carried forward and upward on the outside periphery of the rim until a point is reached, when it is held in position by the shield, and towards the end of its travel it is pushed, as in a scraper conveyor, till it reaches the outlet at the highest point, where delivery to the locomotive tender takes place by a hinged shoot. The angle of repose α of the coal determines the point at which the shield begins.

B.—ELEVATORS FOR LARGE OBJECTS

Elevators of a somewhat similar construction to the foregoing are frequently used for handling sacks, packing cases, carcasses, casks, blocks of ice, etc.; but of course

¹ *Zeitschrift des Vereines deutscher Ingenieure*, 7th August 1909, page 1283.

the elevator buckets, or their equivalents, which have to deal with these large objects, must be shaped according to the loads they are intended to carry. The methods of feeding on or off vary also materially from those elevators described previously.



Figs. 31 and 32. Rigid Arm Elevator. Built by the Ewart Chain Belt Co. Ltd.

This does not, however, apply to the elevators for ice in large blocks of say 50 to 60 lb., as these are more like the ordinary elevator but on a very large scale, with double long-link chains running over polygonal terminals. The buckets are a long way apart, so that only one at a time is on the terminal, and the latter is fitted with two revolving shoots for the delivery of the ice. These shoots are similar to those shown in Fig. 13,

but only two buckets instead of four are discharged with each revolution of the terminal.

Rigid Arm Elevators.—The type of continuous elevator shown in Figs. 31 and 32 is extensively applied to the handling of bags, bundles, barrels, and rolls of linoleum, carpets, and felting. The first cost is low, the space occupied small, the power absorbed insignificant, but the saving in labour considerable.

A rigid arm elevator consists of two strands of chain running over two top and two bottom wheels of small diameter, together with the necessary shafts, bearings, reducing gear, and framing. Fastened to the chains at intervals of, say, 10 ft. are projecting arms and struts, shaped to suit the packages to be raised. These arms pick up the packages as fast as they can be placed on the loading grid, and discharge them as the arms pass over the top wheels. Obviously, with this type of elevator there can be only one loading point and one discharge point. Light packages, however, may be removed by hand on the ascending side at any point before reaching the upper terminal.

Similar elevators are used successfully on an incline for handling loose pieces of cloth in finishing factories, wood slats being arranged above the carrying arms to prevent the cloth coming in contact with the chains.

It is sometimes required to discharge the packages on the ascending side of an elevator instead of over the top shaft, and this necessitates a special artifice, as shown by Fig. 33. The top wheels are made of large diameter, and deflecting wheels are added in order to cant the carriers sufficiently for the package to slide off. This principle

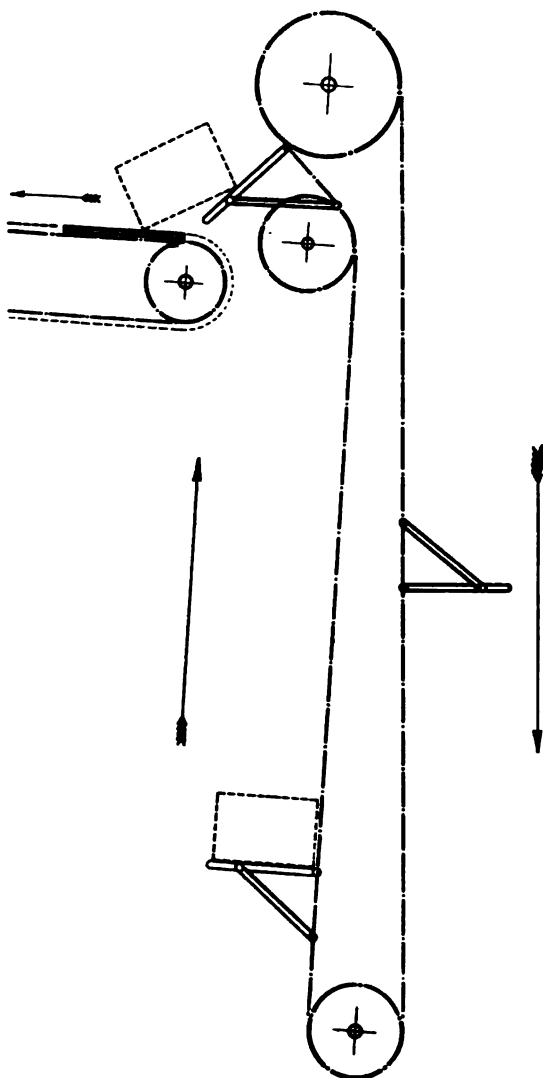


Fig. 33. Type of Rigid Arm Elevator, showing Delivery on the ascending side. Built by the Ewart Chain Belt Co., Ltd., Derby.

has been applied to an elevator transferring bales of paper pulp automatically to a slat conveyor erected at a large paper works.

Swing Tray Elevators and Lowerers.—A rigid arm elevator is not applicable when several floors have to be served, and where lowering is required as well as

elevating. Further, some classes of goods would suffer injury if thrown off upside down at the delivery point. Hence, for handling goods in bottles, crates, and baskets, the

Figs. 34 and 35. Swing Tray Elevator, in two views.

swing tray type of machine is adopted, as illustrated in Figs. 34 and 35, which show an installation erected by the Ewart Chain Belt Co., Ltd., Derby, for Messrs W. H. Holmes & Sons, London, for handling tins of paint.

The swing tray elevator or pivoted carrier consists of a series of flat trays or carrying platforms suspended at intervals of a few feet between two endless chains running over

top and bottom wheels, together with the necessary driving gear and supporting framework. Guides are also desirable, though sometimes omitted. The packages are generally loaded on the ascending side; but they can be removed from either the ascending or descending trays as may be most convenient. If the packages are not removed they simply go round the circuit again. This is a feature of some importance.

Obviously, if the carriers were rigidly attached to the chains the package would be thrown off in passing over the top shaft, but as they are freely pivoted to the chains and the centre of gravity is kept well below the point of suspension, the constant force of gravity preserves the stability of the suspended carriers when passing between the top wheels.

The carrying capacity of a swing tray elevator is very high. Thus, if the trays are placed 5 ft. apart, and the chain speed is only 40 ft. per minute, the rate of working will be 8 packages per minute, or 480 per hour, which can sometimes be increased to twice that number by placing two packages on each tray. Should this rate of working be too great for the particular service required, then the distance apart of the carriers can be increased or the speed of the chain reduced.

The theoretical carrying capacity can be multiplied indefinitely by placing the swing trays closer together and running the chain faster; but the practical limit is fixed by the quickness of the persons feeding and unloading the elevator. This limit is reached when the trays are about 4 ft. apart and the chain speed is about 60 ft. per minute, thus giving a time interval of 4 seconds and a capacity of 15 trays per minute, or 900 per hour.

Naturally the actual rate of working depends a good deal on the size and weight of the packages, the best results being obtained when handling small packages of nearly uniform size and weight. Skips full of cotton cops or bobbins weighing 90 lb., however, can be handled quite successfully at the rate of three a minute, even by young lads, when using suitable loading tables, from which the skips are slid on to the slowly ascending swing trays without being lifted bodily, and slid off the trays at the various unloading points, which are fitted with short roller runways.

The power required to drive a swing tray elevator is surprisingly small. A motor of 1 H.P. is often sufficient, and a large elevator serving seven floors is easily driven by a 5 H.P. motor when handling a steady stream of packages. This economy of power results from the elevator being perfectly balanced, coupled with the slow speed of the main shafts, and the continuous uniform motion of the chains and carriers.

Swing tray elevators are preferably driven at the top and the tension screws placed at the bottom. Then, if the chains are allowed to become slack, their own weight will maintain contact with the top wheels, and the load on the shaft bearings is a minimum. Sometimes these elevators are driven at the bottom, when power is not available on the top floor; but the load on the shaft bearings is thereby increased, and the chain must be kept taut all round the circuit.

It is specially important that the chains should be of ample strength and bearing surface, and provided with suitable attachments for the reception of the pivoted carriers or swing trays. For heavy elevators the Gray pin chain is suitable, while for light duty the Ewart or pinless type of chain is most commonly employed.

Where floor space is restricted and existing machinery is to be cleared, it is sometimes necessary to crank an elevator to get it in the space available, as in the example shown in Fig. 36. This machine lifts and lowers tall cans full of hemp sliver at the rope factory of Messrs Hawkins & Tipson, Blackwall, and was built by the Ewart Chain Belt Co., Ltd. It effectively solved a rather difficult problem. Evidently a cage hoist was inapplicable.

Swing Tray or Finger Tray Elevators and Lowerers with Automatic Loading and Discharging Gear are adopted for raising heavier packages than can be moved conveniently by one man, and can often be applied with advantage for

Fig. 36. Cranked Elevator.

much lighter packages, instead of the simple swing tray type. In this modification (Figs. 37 and 38) each pivoted carrier is composed of a centre bar with transverse arms, slung from the chains by two hangers, which are usually malleable-iron castings. At each floor are provided loading and discharging brackets or grids, arranged to intermesh

with the carriers. A box, bag, bale, or barrel placed on any loading grid is gently picked up by the first ascending carrier, taken over the top shaft and down to the delivery point. Here it meets the inclined discharging arms or fingers, which intercept



Fig. 37.

Finger Tray Elevators for Tea Chests, etc.

Fig. 38.

and remove the package, while permitting the carrier to pass. Both the loading and discharge grids are hinged for throwing them out of position when not in use at any floor, thus enabling the package to pass to the next floor. In this way a regular stream of packages can be delivered automatically at any pre-determined floor. By suitably

shaping the carriers or cradles, the same elevator can be used for handling both boxes and barrels simultaneously.

Sack Elevators.—The elevator shown in the illustration, Figs. 39 and 40, is

Figs. 39 and 40. Hall's Elevator for Handling Sacks.

for handling sacks; those for handling barrels and carcasses are similar, with this exception, that the appliances for the receiving and delivering of the loads are somewhat different. Fig. 41 shows to a larger scale this portion of elevators for handling sacks, whilst Fig. 42 shows the same for barrels.

Much of the frozen meat, especially mutton, handled in the foreign meat market, is exceedingly hard when it arrives; but some of it, especially chilled beef, is in a very different condition, and the less it is handled the better.¹

These mechanical devices are therefore very serviceable, not only as labour-saving appliances, but also on account of their ability to handle the material with less injury than is usually the case with hand labour.

The hoist consists of two pairs of chains which run over two pairs of sprocket wheels, one pair being fixed on the top floor and the other on the bottom floor. Attache to the chains at certain intervals are cage-shaped buckets, arranged to take sacks, barrels, or the carcasses of animals. Each receptacle will take a whole sheep or a quarter of beef. The cages being suspended above their centre of gravity, are always

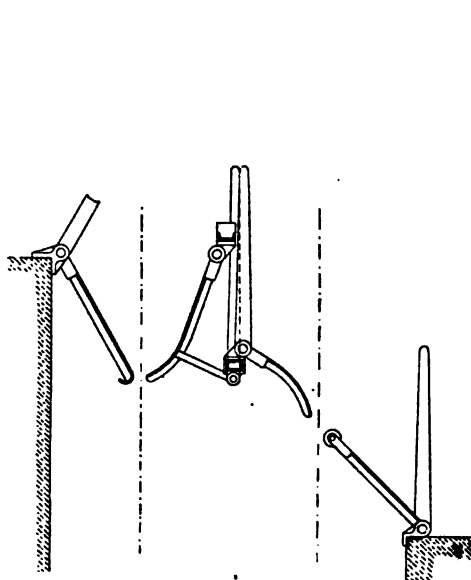


Fig. 41. Elevator for Handling Sacks.

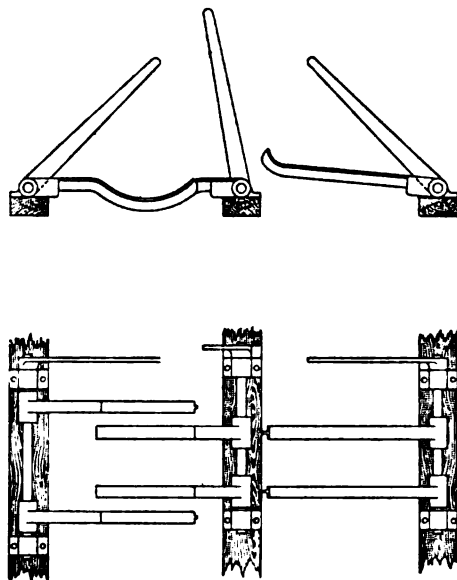


Fig. 42. Elevator for Handling Barrels.

in a perpendicular position. They are loaded on any floor that may be convenient and deliver automatically on to any other floor as may be required.

On each floor there is a delivery platform, consisting of five or more steel arms, which may be set to deliver or to receive, or may be moved out of the way altogether by the system of levers which may be worked from any of the floors. Thus at the floor on which the meat, etc., is loaded, the steel platform is set to deliver the carcasses to the cages as they pass, the cages being formed also of steel bars which clear the steel arms of the platforms.

The carcasses are merely placed on these platforms, and find their way, one after another, into the cages as they arrive on the levels of the floors. They pass with the elevator chains over the top sprocket wheels, and as soon as they arrive on one of the delivery platforms the loads are arrested whilst the cages pass on. The platform is inclined at an angle sufficient to allow the load to slide down on to the floor of the warehouse. Here the meat is taken up by the man who is attending to the storage, and passed by him into the proper bin.

¹ For another form of sack elevator see Figs. 724 and 725.

Fig. 43. Example of an American Finger Tray Elevator for Handling Blocks of Ice.

All the platforms of the floors which are not required for loading and receiving are thrown out of the way by the arrangement of levers already mentioned, which controls the whole system.

Loading, it will be understood, takes place on the rising side of the elevator, whilst delivery is effected on the descending side. Thus if the cage is set to load, say, on the bottom floor of the loading side, the elevator delivers on the other side on the top floor.

All the steel platforms on the loading side may be left undisturbed, as they will be pushed out of the way by the first loaded cage which passes. All those on the delivery side are moved into a vertical position, except those on the top floor, where the carcasses are arrested by a projecting steel platform as previously described, and deposited on the floor.¹

A similar elevator, of the type used in the United States in ice-houses, for handling blocks of natural ice, is shown in Fig. 43. Unlike the previous appliances, this elevator is self-contained, in timber construction, there being no floors in ice-houses. The principle being the same as in the devices previously described, a detailed description is omitted.

¹ The illustrations (Figs. 32 to 39) and descriptions are from a paper on "Continuous Package Conveyors for Factories," read by Mr W. H. Atherton (General Manager of the Ewart Chain Belt Co., Ltd., Derby) before the Manchester Association of Engineers on the 15th February 1913; while Fig. 43 is from "Ice and Refrigeration," to whom the author acknowledges his indebtedness.

CONVEYORS

- A. APPLIANCES CONSISTING OF A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A CONTINUOUS PUSHING DEVICE.
- B. APPLIANCES WITH A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A RECIPROCATING PUSHING DEVICE.
- C. APPLIANCES IN WHICH THE TROUGH CONTAINING THE MATERIAL MOVES BODILY WITH THE MATERIAL.
- D. APPLIANCES IN WHICH THE MATERIAL IS CONVEYED BY THE ACTION OF A SEMI-STATIONARY RECIPROCATING TROUGH.

CHAPTER III

INTRODUCTORY REMARKS

By the name conveyor is generally understood a machine for mechanically transporting materials in a horizontal or slightly inclined direction. In the following seven chapters conveyors of different types are dealt with. Before, however, entering into the description of these various appliances, their utility, peculiarity, capacity, and the driving power required, it will be well to give a few introductory remarks as to the behaviour of different materials when being handled by these various machines.

Conveyors of almost all known forms of construction are more or less suitable for the mechanical handling of such materials as minerals, coal, coke, stone, clinker, gravel, seeds, cereals, oil seeds and nuts, but small materials such as cement, plaster of Paris, fine sand, and the powders produced by grinding or crushing the first named substances, as well as sugar, salt, and spices, are all more or less difficult to handle, and indeed only a limited number of types of conveyor can be used for this purpose, and even then often only with indifferent success.

The reasons why fine material is so much more difficult to handle than coarse are various, and one of the principal is the production of dust at the slightest agitation, so that a conveyor which moves the material by a stirring, pulling, or pushing device must be enclosed, to prevent the escape of dust and consequent loss, as well as injury to the workmen. Even with conveyors which perform their functions without this agitation, and in which the material is carried as it is on a belt conveyor, the usual high speed at which these appliances work will create dust by the resistance of the air to the passage of the material.

There are also other difficulties, caused by the great difference in the consistency of fine materials. Some are of a lively nature and run through the fingers if an attempt is made to get a handful, and this class of stuff needs a close-fitting conveyor, say of the push-plate or worm type, for its handling, as on a belt conveyor there is a great tendency for it to run off, unless the belt is well troughed. Other fine materials are of

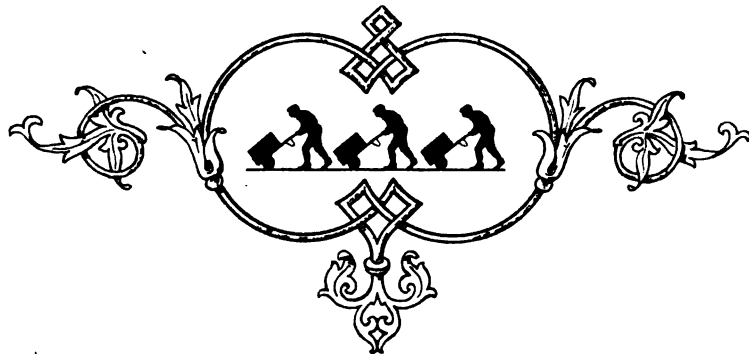
just the opposite nature, almost dead, as, for instance, cement, and if conveyed in a push-plate conveyor have a tendency to lie at the bottom of the trough and let the scrapers travel over the top.

Then, again, there is a difficulty in handling fine materials on account of the tendency of small particles to enter the working parts of the conveyor, and if the material is of a sharp and cutting nature this is the principal objection to the use of conveyors in which the material comes in contact with the chain or other moving parts, as such parts are soon destroyed by wear and tear.

It will thus be seen that for the conveying by mechanical means of fine materials the utility of the existing types of conveyors is considerably restricted. Belt conveyors can be used if the material can be fed on and off without causing dust, and also if the belt travels sufficiently slowly. Whilst all conveyors with agitators can only be used when running slowly or when completely covered in, this is sometimes difficult, particularly with push-plate conveyors, the general construction of which would not permit of covering without complications.

The Zimmer conveyor of reciprocating type appears to be very suitable for handling fine material, because the trough can easily be covered with a dust-tight lid, and there are no stirring or pushing elements to create dust or which are subject to wear; but again there is an objection, and that is that with this type of conveyor fine material can only be conveyed satisfactorily in a very thin layer, and then preferably on a slightly downward gradient, so that here the same objection holds good as with the belt conveyor. Both can be made to do the work, but the capacity is small on the belt conveyor on account of the slow speed, and on the Zimmer conveyor on account of the thin feed, so that both these types, if used for fine material, would have to be made rather wider, and therefore more expensively, for capacities which could be conveyed on small conveyors if the material were coarser.

As a *résumé* of the foregoing, push-plate, belt, and Zimmer conveyors cannot be looked upon as the best means of handling fine material under general conditions, so there is only the worm conveyor left. This can be fitted with a dust-tight lid, inlets and outlets, and it has a moderate capacity. It does the work well if the material is not of a cutting nature, and is inexpensive in first cost, but for long distances and large capacities it presents drawbacks which make it not much better than the other types. The driving power consumed is higher than for any other conveyor, and with sharp and cutting stuff the wear and tear on the ordinary intermediate bearings, which must of necessity work surrounded by the material to be conveyed, is very great.



CONVEYORS

A.—APPLIANCES CONSISTING OF A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A CONTINUOUS PUSHING DEVICE

CHAPTER IV

WORM OR ARCHIMEDEAN SCREW CONVEYORS

THE worm or Archimedeal screw is undoubtedly the oldest type of mechanical conveyor, and it has long been the only one for fine materials. This simple mechanism, with all its good and bad points, has been practically unsurpassed till within comparatively recent years.

The history of the worm conveyor is difficult to trace, and it is probable that the flour miller was the first user of this labour saver. Whatever purpose the worm conveyor might have served at the time of its supposed invention by Archimedes (287-212 B.C.)

Fig. 44. Earliest Construction of Worm Conveyor.

we know for certain that a crude form of it was employed in flour mills by Oliver Evans, in Philadelphia, over 130 years ago.

The nature of the worm conveyor is such that only comparatively fine material can be conveyed satisfactorily, and at the time when this conveyor was the only mechanical one, all materials consisting of pieces too large for this type of conveyor were debarred, and had to be moved by hand labour.

Worm conveyors are of the simplest possible construction. They consist of a continuous or broken-bladed screw fixed to a revolving spindle, and the whole is mounted in a suitable trough, so that the revolving screw slowly propels the material fed in at one end of the trough to the other end.

The first specimens of worm conveyors were made of soft wooden octagonal spindles into which round holes were bored, and into these holes were driven hard wood blades with square pegs or shanks. Such a worm is illustrated in Fig. 44.

In course of time this construction was improved upon by cast-iron spiral sections being threaded on a square iron shaft, which was turned for suitable bearings at intervals from 6 to 10 ft.

Fig. 45 shows such a conveyor, but both this and the wooden type are quite antiquated now.

More modern constructions used at the present day are illustrated in Figs. 46 and 47. They were probably introduced at the beginning of the nineteenth century.

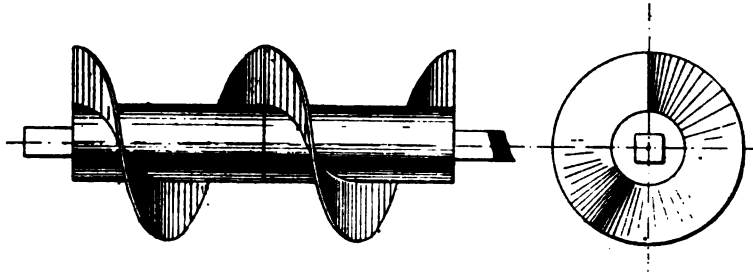


Fig. 45. Worm Conveyor composed of Cast-Iron Blades and fitted with Square Spindle.

Fig. 46 represents a so-called paddle worm constructed of a series of blades forming together as nearly as possible a complete screw. Each of the blades is fixed to a central shaft or spindle by means of its shank, which is tapped and fitted with a nut. The

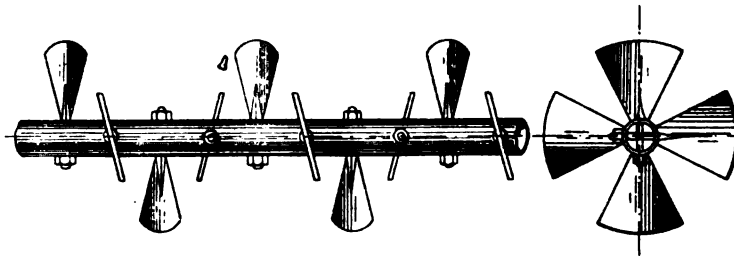


Fig. 46. Paddle Worm, or Broken-bladed Conveyor.

spindle is made of steam pipe in lengths of about 8 ft., the different lengths being coupled together by turned gudgeons, which answer at the same time as journals for the bearings.

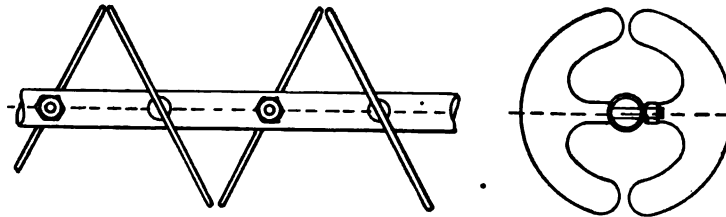


Fig. 47. Worm with Crescent Blades.

Another type of conveyor akin to the broken-bladed worm is that known as the crescent-bladed worm, Fig. 47. Each paddle is extended in the form of a crescent, so that it forms practically a semicircle held out from the spindle by the shank. Two crescents form one complete spiral, and thus only two blades are required instead of

four of the ordinary paddles, so that only half the number of holes are required on the spindle.

The chief advantages of the paddle-bladed and crescent-bladed worms are that, if for any reason it may be desired to change the direction in which the material is being conveyed, it is only necessary to slacken the nuts on the shanks and turn the blades to the reverse angle. The crescent blades in this case still form a continuous screw, but the paddle blades on being reversed form a broken non-continuous worm, and though this will still convey the material in the right direction, it will only convey it the width of a paddle at each revolution; that is, only at a quarter of the proper speed. It is therefore necessary to remove every other blade and replace it on the other side of the spindle, when the worm will again be practically continuous.

The continuous or closed spiral worm is illustrated in Fig. 48. The only difference

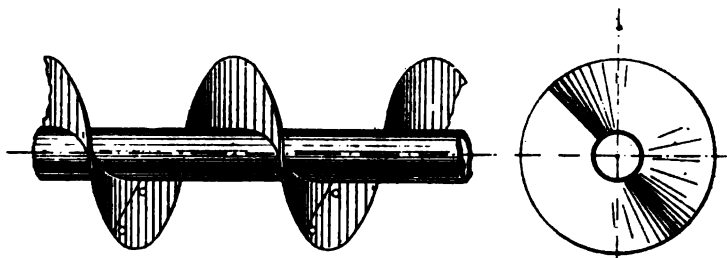


Fig. 48. Continuous Worm Conveyor, or Closed Spiral.

between this and the last-mentioned conveyor consists in this, that the screw is not composed of single blades, but is one continuous sheet-iron spiral, which is secured to the spindle at intervals more or less frequent according to the size and capacity of the worm. The most approved method of construction is to cut a narrow spiral groove in the spindle, and to secure the sheet-iron spiral into this groove.

The usual method employed for producing the close spiral of a continuous worm conveyor has been to cut segments from sheet iron and rivet them together. A later and better method is to run a strip of hoop iron through special rollers in such a way as to thin and therefore stretch it at the outer edge, tapering to the inner edge, whereby a spiral is produced. This is probably the best method for worm conveyors intended for heavy and cutting materials, as the iron strip or hoop may be chosen of any gauge. One of the latest methods of producing the spiral is also from a strip of light hoop iron, but instead of rolling it down to a tapering section the inner periphery is reduced, thus forming a spiral by a series of triangular pleats, as shown in Fig. 49. This does not only produce a very rigid spiral from comparatively light material, but the projecting pleats also aid the conveying action by offering more resistance to the material to be handled than a smooth blade. Of course the worm must be so arranged that the pleats are on the conveying side of the worm, *i.e.*, point in the direction in which the material is to be conveyed. Such a worm would be most suitable for grain and similar light materials.

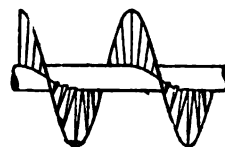


Fig. 49. Showing Construction of Closed Spiral Worm.

There is a fourth form of worm which comes under this heading, *i.e.*, the open spiral, sometimes called an anti-friction conveyor. This was introduced about the year 1887, and is a very simple yet efficient conveyor.

Fig. 50 illustrates this appliance, which has the advantage of being inexpensive.

The spirals which form the principal part are rolled by special machines. The illustration shows the mode of fixing the spiral to the spindle.

Fig. 51 shows another method for this.

The spirals are made of various sections, from a round bar about $\frac{1}{2}$ in. in diameter to L or T section. The best form, however, is the flat bar, as shown in the illustration.

In all worms the ratio of the pitch to the diameter must depend upon the kind of material to be conveyed. It ranges from one-quarter to a pitch equal to the diameter of the worm, and even sometimes more. The greater the pitch the greater the capacity and consequently driving power required. It is therefore usual to employ worm conveyors for specifically heavy materials, such as cement, with a small pitch, and those for grain and other light materials with a larger pitch.

The space between the screw and the trough should be either as small as possible

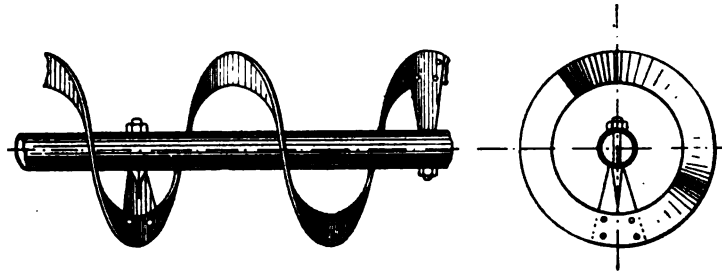


Fig. 50. Open Spiral or Anti-friction Worm Conveyor.

or just a little larger than the size of the largest piece contained in the material to be conveyed, as if fractions of the material are larger than the space, they become wedged between the screw and the trough, and may thereby cause trouble.

Well-made worm conveyors, with well-fitting troughs—*i.e.*, not too tight—of

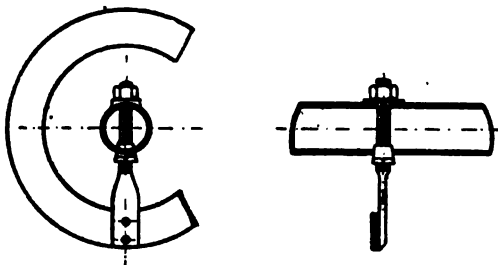


Fig. 51. Method of Fixing Spiral of Conveyor to Spindle.

sufficient rigidity not to require too many intermediate bearings, with the latter of a design not to obstruct the flow of the material, are undoubtedly good and serviceable conveyors for all flour-mill products, meal, seeds, cereals, cattle food, crushed seed cakes, material used in the manufacture of linoleum, such as cork powder and sawdust, and as a matter of fact for all fine materials which are not gritty or cutting, always provided the worms are not too long and are not required for too large a capacity.

Worm conveyors of the continuous paddle or spiral types are made with diameters of from 4 in. to 18 in. and even more, but those of 12 in. and over, except for short distances of, say, not exceeding 40 to 50 ft., and for the materials just mentioned, can hardly be called satisfactory. As to the worms of the smaller diameters and for the same materials, lengths not exceeding 150 ft. for 4-in. to 8-in. worms, and 100 ft. for 9-in. to 10-in., should be the limit of their economical utility.

It is true that there are installations to be found in which these limits are exceeded, but they cannot be called economical. In the end it comes to this, that before the

introduction of the Suess conveyor (page 56) there was not a suitable conveyor for really heavy work of this class, and worms were used because there was nothing better.

Close-bladed or continuous worms are also made with a larger pitch for lighter material, generally with a pitch of about two-thirds their diameter. These answer their purpose well, as the capacity of these continuous conveyors is nearer the theoretical capacity than is the case with open spirals or with paddle worms. The reason why closed spiral worms are not often made with a pitch more than two-thirds to three-quarters of their diameter is that it is difficult to bend or roll the blades to a large pitch, but their greater efficiency brings their capacity up to nearly that of paddle and open spirals of a larger pitch.

The following tables give the capacity of continuous, paddle, and spiral worm conveyors of different diameters with their respective pitch and speed. It is obvious that the capacity of a continuous worm is greater than that of a paddle or open spiral conveyor, these two latter being about equal in capacity if other conditions are equal.

Conveyors of double pitch have twice the capacity, and should be driven, if more than 9 in. in diameter, by means of gearing and countershaft, unless they are very short.

CAPACITY OF SMALL PITCH WORM CONVEYORS OF THE CONTINUOUS OR CLOSE-BLADED TYPE FOR HEAVY MATERIALS

Diameter.	Pitch.	Diameter of Hollow Spindle.		Revolutions per Minute.	Capacity.
		Inner.	Outer.		
Inches.	Inches.	Inches.	Inches.		Cubic Feet per Hour.
4	2	1	1 $\frac{1}{8}$	130	30
6	3	1 $\frac{1}{2}$	1 $\frac{1}{4}$	120	60
8	4	1 $\frac{1}{2}$	1 $\frac{1}{4}$	100	180
9	4 $\frac{1}{2}$	1 $\frac{3}{4}$	2 $\frac{1}{8}$	100	250
10	5	2	2 $\frac{1}{8}$	90	300
12	6	2	2 $\frac{1}{8}$	90	600
14	7	2 $\frac{1}{2}$	2 $\frac{1}{4}$	80	900
16	8	2 $\frac{1}{2}$	2 $\frac{1}{4}$	70	1,000
18	9	2 $\frac{1}{2}$	2 $\frac{1}{4}$	60	1,300

TABLE GIVING DIAMETER, PITCH, AND CAPACITY OF THE CONTINUOUS OR CLOSE-BLADED WORM OF THE MORE USUAL CONSTRUCTION FOR LIGHT MATERIALS

Diameter of Worm.	Pitch of Worm.	Outer Diameter of Hollow Spindle.	Diameter of Internal Bearings and End Gudgeons.	Revolutions per Minute.	Capacity in Cubic Feet per Hour.	Length between Bearings.
Inches.	Inches.	Inches.	Inches.			
4	4	1 $\frac{5}{8}$	1	130	70	8 feet.
5	5	1 $\frac{3}{4}$	1 $\frac{1}{2}$	120	100	
6	6	1 $\frac{7}{8}$	1 $\frac{1}{2}$	120	175	
7	6	1 $\frac{7}{8}$	1 $\frac{1}{2}$	110	250	
8	6	1 $\frac{7}{8}$	1 $\frac{1}{2}$	100	300	10 feet.
9	8	2 $\frac{3}{8}$	2	100	400	
10	8	2 $\frac{3}{8}$	2	90	500	
11	10	2 $\frac{3}{8}$	2	90	650	
12	10	2 $\frac{3}{8}$	2	90	850	12 feet.
13	10	2 $\frac{1}{2}$	2 $\frac{1}{2}$	80	1,000	
14	10	2 $\frac{1}{2}$	2 $\frac{1}{2}$	80	1,200	
15	12	2 $\frac{1}{2}$	2 $\frac{1}{2}$	70	1,350	
16	12	2 $\frac{1}{2}$	2 $\frac{1}{2}$	70	1,550	
18	12	2 $\frac{1}{2}$	2 $\frac{1}{2}$	60	1,800	

TABLE GIVING DIAMETER, PITCH, AND CAPACITY OF THE OPEN-BLADED OR SPIRAL CONVEYOR FOR HEAVY AS WELL AS FOR LIGHT WORK

Diameter of Spiral.	Pitch of Spiral.	Diameter of Solid Shaft.	Section of Spiral.	Speed for Heavy ¹ Materials. Revs. per Minute.	Capacity for Heavy Materials in Cubic Feet per Hour.	Speed for Light ² Materials. Revs. per Minute.	Capacity for Light Materials in Cubic Feet per Hour.
Inches.	Inches.	Inches.	Inches.				
4	4	1½ to 1½	1½ × ⅞	100	40	130	60
6	5	1½	1½ × ⅞	90	120	120	150
8	6	1½ to 2	1½ × ¾	80	230	110	300
10	7	2 „ 2½	2½ × ¾	70	350	100	500
12	8	2 „ 2½	2½ × ¾	60	550	90	800
14	9	2½ „ 3	2½ × ¾	60	700	80	1,100
16	10	2½ „ 3	3 × ¾	50	950	70	1,400
18	11	2½ „ 3	3½ × ¾	40	1,100	60	1,700
20	12	2½ „ 3	3½ × ¾	35	1,300	50	1,900
22	13	3 „ 3½	3½ × ¾	30	1,500	40	2,100
24	14	3 „ 3½	3½ × ¾	25	1,600	35	2,300

TABLE GIVING DIAMETER, PITCH, AND CAPACITY OF PADDLE WORMS

Diam. of Worm.	Pitch of Worm.	Outer Diam. of Hollow Spindle.	Diam. of Intermediate Bearings and End Gudgeons.	Diam. of Shank of Blade.	Speed for Heavy ¹ Materials. Revs. per Minute.	Capacity for Heavy Materials in Cubic Feet per Hour.	Speed for Light ² Materials. Revs. per Minute.	Capacity for Light Materials in Cubic Feet per Minute.
Inches.	Inches.	Inches.	Inches.	Inches.				
4	4	1½	1	⅞	85	28	120	40
5	5	1½	1½	1⅞	85	65	120	90
6	6	1½	1½	⅞	80	110	110	170
7	7	1½	1½	⅞	80	175	110	260
8	8	1½	1½	⅞	70	220	100	330
9	9	2	1½	⅞	70	320	100	470
10	10	2½	2	⅞	60	400	90	600
11	11	2½	2½	⅞	60	500	90	750
12	12	2½	2½	⅞	60	600	90	900
14	14	2½	2½	⅞	55	1,000	80	1,300
16	16	3½	3	⅞	50	1,350	70	1,800
18	18	3½	3	⅞	50	1,800	60	2,200

Experiments with "Paddle" and "Spiral" Worm Conveyors.—In order to ascertain the respective merits of spiral worm and paddle worm conveyors, the author carried out a series of experiments in March 1889, which point to the fact that when running at a slow speed the paddle worm is of greater efficiency, while with a high speed the advantage is on the side of the spiral worm. At a speed—for 4-in. worms—of 150 revs. per minute the efficiency of both is about equal, while if run at higher speeds the spiral worm increases and the paddle worm decreases in capacity.

The following is a summary of the results of the experiments. The material experimented with was sawdust.

¹ Heavy materials include fine coal, cement, sand, ground minerals, fine gravel, plaster of Paris, oxide of iron, etc.

² Light materials include grain, seeds, sugar, flour, meal, bran, ice, sawdust, rice, etc.

First Experiment.—The worms experimented with consisted of a paddle worm $4\frac{1}{2}$ in. in diameter by 6 in. pitch, with a spindle of an external diameter of $1\frac{1}{2}$ in., and an open spiral worm 4 in. in diameter by 3 in. pitch, on a 1-in. spindle. Paddle worm without intermediate bearing. Spiral worm with one intermediate bearing. Speed of both, 145 revs. per minute.

	Paddle.	Spiral.
Actual capacity in bushels per minute	2.77	1.11
Theoretical capacity in bushels per minute	5.545	2.297
Efficiency, per cent.	49.95	48.324

Second Experiment.—Both worms as above, but the speed of both 300 revs.

	Paddle.	Spiral.
Actual capacity in bushels per minute	3.55	1.97
Theoretical capacity in bushels per minute	11.475	4.762
Efficiency, per cent.	30.9	41.3

Third Experiment.—Both worms reduced to half their length, so that neither had an intermediate bearing, and both running at 300 revs.

	Paddle.	Spiral.
Actual capacity in bushels per minute	4.44	2.61
Theoretical capacity in bushels per minute	11.475	4.762
Efficiency, per cent.	38.69	54.81

Power Required to Drive Worm Conveyors.—The driving power required for worm conveyors depends chiefly upon the weight of the material to be moved, and the distance which it has to be conveyed. The type of the worm, its diameter and speed, enter to a smaller degree into the calculation. It will therefore be sufficient guide to give two tables, one for light and one for heavy materials, from which the approximate horse power can be found.

TABLE GIVING APPROXIMATE HORSE POWER REQUIRED TO DRIVE A WORM CONVEYOR FOR GRAIN OR OTHER LIGHT MATERIAL.

Tons per Hour.	Length of Conveyor in Feet.									
	10	20	30	40	50	60	70	80	90	100
5	0.19	0.38	0.57	0.76	0.95	1.14	1.33	1.52	1.71	1.90
10	0.38	0.76	1.14	1.52	1.90	2.28	2.66	3.04	3.42	3.80
15	0.57	1.14	1.71	2.28	2.85	3.42	3.99	4.56	5.13	5.70
20	0.76	1.52	2.28	3.04	3.80	4.56	5.32	6.08	6.84	7.60
25	0.95	1.90	2.85	3.80	4.75	5.70	6.65	7.60	8.55	9.50
30	1.14	2.28	3.42	4.56	5.70	6.84	7.98	9.12	10.26	11.40
35	1.33	2.66	3.99	5.32	6.65	7.98	9.31	10.64	11.97	13.30
40	1.52	3.04	4.56	6.08	7.60	9.12	10.64	12.16	13.68	15.20
45	1.71	3.42	5.13	6.84	8.55	10.26	11.97	13.68	15.39	17.10
50	1.90	3.80	5.70	7.60	9.50	11.40	13.30	15.20	17.10	19.00

For the sake of easy comparison with other conveyors, the following estimate is based on a load of 50 tons of grain per hour to be conveyed a distance of 100 ft.

An 18 or 20 in. continuous worm will do the work if driven at 60 revs. per minute, and the power required will be $18\frac{1}{2}$ to 19 H.P. To convey cement would absorb somewhat more power on account of the greater friction of the worm blades and the box against the cement, and the greater specific gravity of the cement.

TABLE GIVING THE APPROXIMATE HORSE POWER REQUIRED TO DRIVE A
WORM CONVEYOR FOR HEAVY MATERIAL

Tons per Hour.	Length of Conveyor in Feet.									
	10	20	30	40	50	60	70	80	90	100
5	0.33	0.66	0.99	1.32	1.65	1.98	2.31	2.64	2.97	3.30
10	0.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94	6.60
15	0.99	1.98	2.97	3.96	4.95	5.94	6.93	7.92	8.91	9.90
20	1.32	2.64	3.96	5.28	6.60	7.92	9.24	10.56	11.88	13.20
25	1.65	3.30	4.95	6.60	8.25	9.90	11.55	12.40	14.85	16.50
30	1.98	3.96	5.94	7.92	9.90	12.28	13.86	15.84	17.82	19.80
35	2.31	4.62	6.93	9.24	11.55	13.86	16.17	18.48	20.79	23.10
40	2.64	5.28	7.92	10.56	13.20	15.84	18.48	21.12	23.76	26.40
45	2.97	5.94	8.91	11.88	14.85	17.82	20.79	23.76	26.73	29.70
50	3.30	6.60	9.90	13.20	16.50	19.80	23.10	26.40	29.70	33.00

The principal advantages of a worm conveyor consist in its great simplicity and small first cost. The terminals are much less expensive than those of most other types of conveyors. Short worm conveyors can, therefore, be procured at a much smaller cost than short conveyors of other types.

Worm conveyors are of great service where a mixing of the material to be conveyed is desired. For example, when cement and sand in a dry state are to be conveyed, they will arrive at the delivery end well mixed.

The disadvantages are the large amount of driving power required, the grinding action on the material being conveyed, and the great wear and tear if the conveyor be used for hard and cutting substances.

Troughing and Intermediate Bearings of Worm Conveyors.—Worms are fitted into a wooden or iron trough so as to leave a clearance between the revolving and stationary parts of from $\frac{1}{8}$ to $\frac{1}{4}$ in. The different lengths are supported at intervals of 8 ft. for 4 in. worms, 8 to 10 ft. for 6 to 10 in. worms, and 10 to 12 ft. for 12 to 18 in. worms. A continuous worm is more rigid than a paddle worm, and may therefore be in slightly longer lengths between the bearings, *i.e.*, have fewer intermediate supports.

A detail of great importance in all worm conveyors is the intermediate bearing; this, if cumbersome, obstructs the passage of the material, a drawback which must be carefully avoided. As all adjustable bearings are in halves and of necessity bulky, it is preferable to choose whole or bush bearings, although they lack some advantages that the former possess. The best intermediate bearing is a small phosphor-bronze bush, connected by a short piece of pipe to a cast-iron support. The pipe is screwed into the support and secured by means of a lock nut. The bearing can be oiled through the pipe. Fig. 52 shows such a bearing, and Fig. 53 a simple form of adjustable bearing in halves.

Fig. 54 illustrates another type of intermediate bearing. It is similar to that illustrated in Fig. 52, with the exception that the bearing is in halves and the cap held in

position by two oblique supports, which give it greater rigidity. Such bearings are suitable for worms of large diameter. The construction almost explains itself, the halves of the bearing being connected by a staple which is U-shaped, and by the two distance pieces which are threaded on the shanks of the staple.

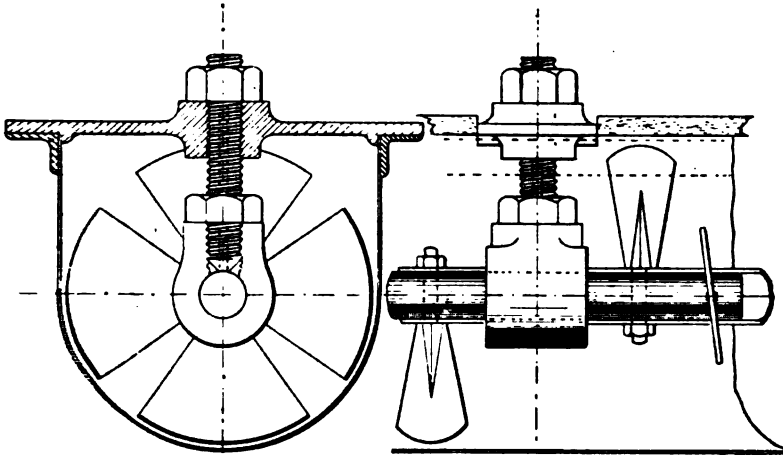


Fig. 52. Solid Phosphor-Bronze Worm Bearing.

Worm conveyors for fine cement and similar materials are frequently built on somewhat different lines, and the tendency is to use more particularly the continuous or closed spiral. The principal differences are the use of a rather larger trough, for instance,

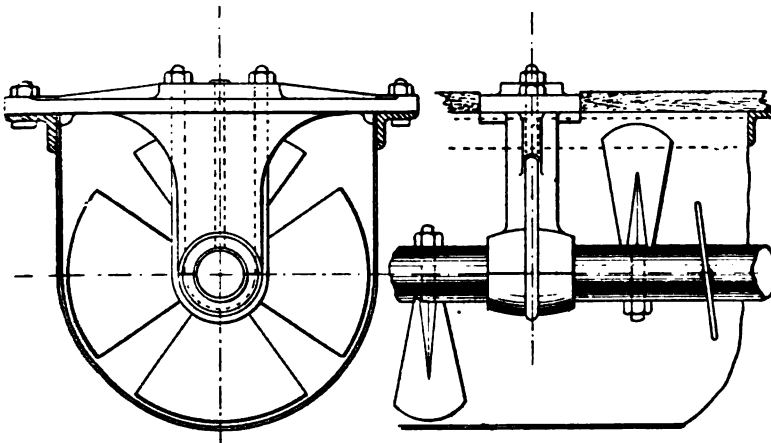


Fig. 53. Worm Bearing in Halves.

an 11-in. trough for a 10-in. worm. This allows of a $\frac{1}{2}$ -in. space between the movable worm and the stationary trough, so that the cement in the worm will form its own trough within the iron trough, and that there is no wear at all on the trough itself. This arrangement, however, causes more wear on the periphery of the worm spiral, which thereby gradually becomes smaller in diameter.

In one of the largest cement works on the lower Thames, where miles of these worms are in use, the practice is as follows: 10-in. continuous worms fitted in 11-in. troughs, with the bearings 10 ft. apart with a pitch of 7 in. and a speed of 80 revs. These worms convey 7, 14, and sometimes even 21 tons of fine cement per hour. As they

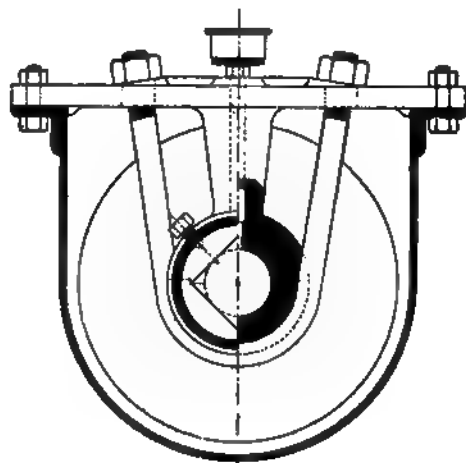


Fig. 55. Cross Section of Worm Conveyor Bearing.

Fig. 54. Worm Bearing in Halves.

are all driven by electric motors the actual horse power consumed was easily obtainable, and from a number of readings the average power was 1 B.H.P. for every 35 ft. of conveyor when handling 7 tons of cement.

The intermediate bearings are similar to Figs. 55 and 56, from which it will be

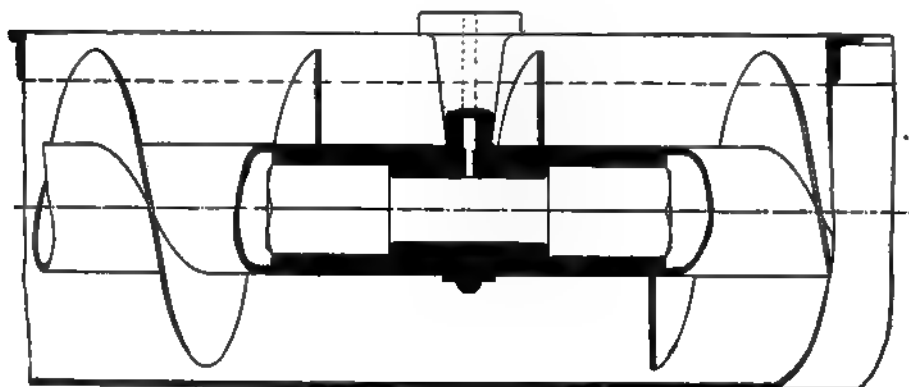


Fig. 56. Longitudinal Section of Worm Conveyor Bearing.

seen that the space between the adjacent sections of the 10-in. worm is very small, only $1\frac{1}{2}$ in.; this is a great advantage, as the break of the blades at the junction is very small and therefore prevents accumulations of the stuff. These bearings have also the further advantage that the working portions are quite away from the injurious influence of the cement.

A similar type of bearing, for which it is claimed that it is perfectly dustproof, may be seen (Fig. 57). It is the design of the Conveyor and Elevator Company of Accrington.

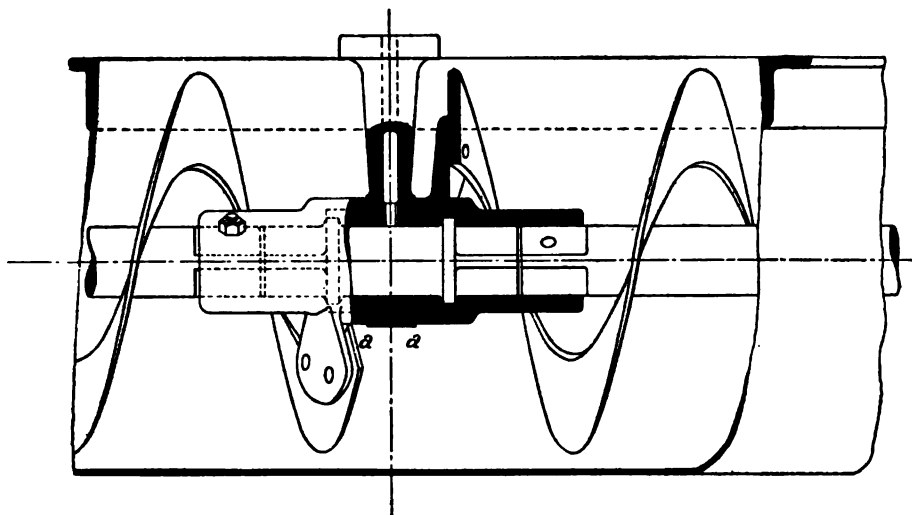


Fig. 57. Dustproof Conveyor Bearing made by the Conveyor and Elevator Co., Accrington, England.

These bearings are lubricated by a viscous grease, which is forced right through the bearing surfaces so that the grease forms a dust collar round the surfaces *a a*.

Couplings for Worm Conveyors.—The different lengths of a worm are coupled

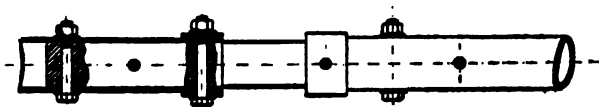


Fig. 58.

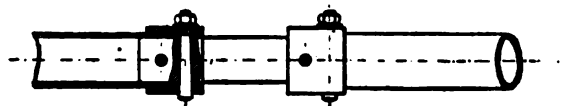


Fig. 59.

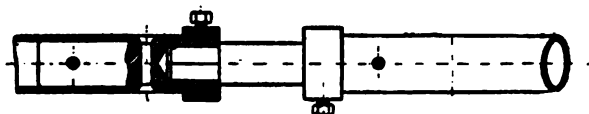


Fig. 60. Types of Worm Couplings.

together in various ways, chiefly by means of gudgeons, a portion of each of which forms the journal for the intermediate bearings. Fig. 58 shows a gudgeon coupling two worm sections. Three bolts, or else the shanks of the worm blades, form the fastening. The end of each worm section is strengthened by a collar which secures the spindle against

splitting. These rings or collars are not necessary when stout steam piping or hydraulic piping is used. Fig. 59 shows another coupling with a short gudgeon, and two cotter bolts for each fastening. In this case the collar over the end of the pipe is indispensable.

Yet another mode of coupling worms together is shown in Fig. 60. The coupling consists of two short gudgeons, each with a square hole into which a short coupling piece fits. The advantage of this coupling is that it can be very quickly disconnected, as it is only necessary to slacken the set-screws and push one-half of the worm 3 or 4 in. to one side, when the coupling piece can be taken out.

Fig. 61 shows a coupling sometimes used in connection with continuous worm conveyors. The coupling consists of a worm section with a stout sleeve which is split longitudinally, and is secured tightly over the junction of the two halves of the worm.

Drummond End Flights.—When handling abrasive or gritty materials with continuous worm conveyors, considerable wear is found on the flights on either side of the intermediate bearing where the worm is of necessity interrupted. This tends to accumulate material, and imposes extra work on the end flights in pushing it past the bearing into the path of the next section. The interruptions pertaining to the repairs of such parts are therefore very considerable, and to minimise them these end flights

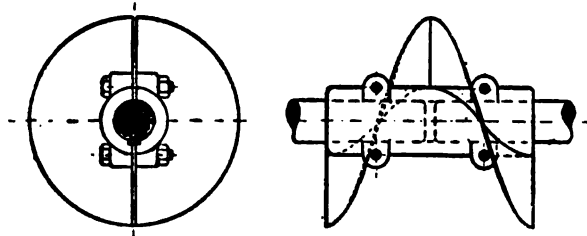


Fig. 61. Coupling for Continuous Worm Conveyor.

have been introduced by the Link Belt Company, and are the invention of the late D. D. Drummond, vice-president and general manager of the Chicago Portland Cement Co. These flights are made of manganese steel, and are easily renewed, being in halves so as to fit the gudgeon. Ordinary end flights, $\frac{5}{8}$ in. thick, have been known to be destroyed in a few weeks by cement clinker, whilst the improved ones show hardly any signs of wear after six months' work on the same material. These worms were probably provided with narrow bearings, as shown in Figs. 56 and 57.

General Remarks.—Delivery of the material from a worm conveyor can be effected at any number of points, it only being necessary to provide a suitable outlet having a slide to open the aperture when necessary. Such an outlet should be as long and as wide as the diameter of the worm if it is desired to get the whole of the feed through it. This must be so, as the worm delivers only on its leading side, and is practically empty on the other side. The lid which covers the worm box or trough should not be fixed, but should lie loose on top, because in the event of an accumulation of material occurring through the choking of a spout, unless the material in the worm can force the lid and throw the stuff out, the worm, if continuous, will be stripped, or the blades broken, if it be a paddle worm.

Tubular Worm Conveyors.—These consist of cylindrical iron tubes with a continuous spiral fitted to the inner periphery, as shown in Fig. 62. When at work the cylinder revolves bodily round an imaginary axis, supported outside by suitable rollers. This type of conveyor does not strictly conform with the attributes given at the heading

of this chapter, as the trough, though stationary laterally, is revolving, but it is essentially a worm conveyor, and is therefore included. The advantages are the absence of internal bearings, which are the principal cause of trouble when using ordinary worm conveyors for material of a cutting nature.

The spiral is best chosen of a width equal to one-third of the diameter of the cylinder, *i.e.*, for a 12-in. worm the spiral strip would be 4 in. wide, and thus leave a clear space of 4 in. in the centre of the tube. The best pitch for the screw is two-fifths of the diameter.

The supporting rollers need not be so close together as the internal bearings of ordinary worm conveyors, as the cylindrical body of the tubular conveyor is so much more rigid. The distance apart of the supporting rollers depends upon the strength of the construction, but as a general rule they may be about twice as far apart as the bearings in ordinary worm conveyors.

Intermediate outlets are not impossible, but they are not advisable owing to the complication and expense.

This form of conveyor is more expensive in initial cost, and the fixing is also more costly than that of ordinary worms, but its life is longer. The introduction of this

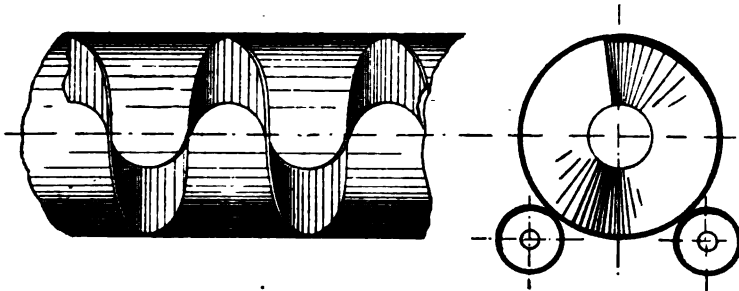


Fig. 62. Tubular Worm Conveyor.

conveyor may be considered to be the first step in the direction of providing a more economical conveyor for fine material.

One of the essential features is that the speed must be chosen within the correct limits. If too high the capacity diminishes, as the centrifugal force counteracts the propulsion; for it must be remembered that with this appliance the forward movement of the material is effected by gravity, inasmuch as through the revolution of the tube the material contained in it is carried up the side in the direction of the revolution until the angle of repose is exceeded, when it is compelled to fall, and is then guided in a slightly forward direction by the spiral attached to the inside of the tube.

The capacity of this tubular conveyor is not very large, as the pitch of the screw must be smaller than with most ordinary worms, say about 0.33 to 0.4 of the inner diameter of the tube, and the number of revolutions is also limited, as already mentioned. It is thus obvious that the greater the pitch of the screw the greater the tendency of the material to cling to the inside of the tube, which tendency is still further encouraged when the centrifugal force begins to exert itself, so that a point is reached where the material is carried too far up the side of the tube, and there is then a tendency for it not to slide forward in its appointed channel but to fall, more than slide, back from its higher position, and so some of the material may fall back into the previous thread of the screw, which reduces the capacity more and more as the speed is increased, and eventually the centrifugal force being greater than the gravity, the material revolves round and round on the inner periphery of the tube, and conveying ceases altogether.

The speed at which tube conveyors should run may therefore be slightly slower for a larger pitch of the screw, and vice versa. The following table gives the most suitable pitch and speed, also the capacity of cylindrical tube conveyors of different diameters :—

Diameter of Tube.	Most Suitable Pitch.	Most Suitable Speed. Revs. per Minute.	Capacity. Cubic Feet per Hour.
6 in.	2 $\frac{3}{4}$ in.	80	40
8 "	3 "	75	100
10 "	4 "	70	200
12 "	4 $\frac{3}{4}$ "	60	300
14 "	5 "	55	350
16 "	6 $\frac{3}{8}$ "	50	550
18 "	7 "	45	700
20 "	8 "	40	900
22 "	8 $\frac{3}{4}$ "	35	1,000
24 "	9 $\frac{1}{2}$ "	30	1,100

A series of experiments with this type of conveyor was made in 1868 prior to the installation of the Liverpool Dock granaries. These were fully dealt with in a paper read by Mr Percy Westmacott before the Institution of Mechanical Engineers. The results of these experiments are here given. A tubular worm, 6 in. in diameter and of 2-in. pitch, with a depth of plate of 2 $\frac{1}{2}$ in. :—

At 60 revs. per minute delivers at the rate of 28 cubic ft. per hour.

" 80 " " " " 36 " "

" 100 " " " " 30 " "

" 140 " " delivery ceased altogether, and the grain was carried round and round the tube.

A second trial was then made with a 30-in. worm, calculated on the results of the preliminary experiment to discharge at the rate of 50 tons per hour. The length of this worm was 18 ft., and it had a pitch of 12 in., or two-fifths of the diameter. The body of the screw was properly balanced and revolved upon finely adjusted rollers, carried in cast-iron frames. With this worm a speed of 36 revs. per minute was found to be the most effective, and at this speed the grain was carried up the side of the screw about 5 in. above the centre of the tubular casing, and the discharge was 63 $\frac{1}{2}$ cub. ft per minute, or about 80 tons of wheat per hour—a much better result than had been calculated upon. The power required was 0.40 H.P. per foot run, and the sectional area of the body of grain was 36 per cent. of the whole area of the casing.

A third experiment was also made with a 12-in. worm, and a pitch of 12 in., with a view to ascertain the effect of the quicker pitch. The worm was driven at the same speed of 36 revs. per minute, the delivery being 10 tons of wheat per hour, with a sectional area of only 17 per cent. The pitch of two-fifths of the diameter proved most effective in these trials.

A case in which the tubular worm conveyor is very useful is where grain has to be conveyed from one building to another on a level, but where no bridge is available to which any other kind of conveyor could be attached. The tube can be made as strong as necessary, and trussed by means of a spider in the middle, and a number of tie-rods, as shown in Fig. 63.

Suess Conveyor.—A decided improvement on the tubular conveyor is the Suess conveyor. It consists of a tube of rectangular section made either of sheet steel or wood.

To the four inner sides of this tube are attached oblique blades, forming an unbroken sequence of oblique channels on each side for the whole length of the conveyor. These blades do not extend across the whole sides of the tube, but are only half as wide as the sides, and leave a longitudinal channel quite unobstructed by blades in each of the four corners of the tube. For example, a 12-in. tube (inside measurement) has blades on each side 6 in. wide, leaving a space of 3 by 3 in. in each corner the whole length of the conveyor.

When at work the action is as follows: Supposing the whole of the material in the conveyor rest all along one of the corners, and as this corner slowly moves upwards the underside of the tube changes its horizontal position for a slanting one, and as soon as the angle is sufficiently steep, the whole of the contents of the corner is forced by the law of gravity to slide across the oblique channels into the next corner, and in doing this it travels forward by the pitch of the channels or blades. This process repeats itself four times in every revolution. The very considerable slope of 45 degrees can be given

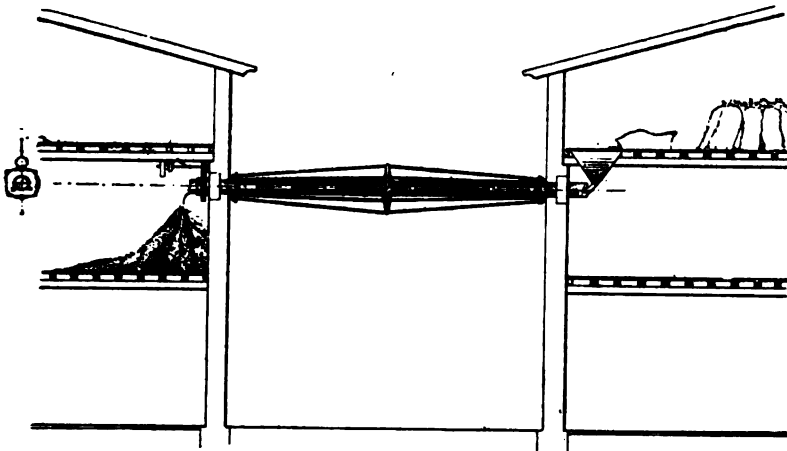


Fig. 63. Example of Tubular Conveyor.

to the blades, so that with each quarter revolution in a 12-in. tube the material moves theoretically 6 in. forward, or 2 ft. with every revolution. This is practically equal to a 12-in. worm with a 24-in. pitch, if it were possible to make such a worm of the ordinary continuous type, which it is not, on account of the difficulty and expense of bending the blades to such a pitch, and for that reason a square tube like the Suess has a much larger capacity than a cylinder of the same size.

With the Suess conveyor a single internal screw formed of four blades would not give a very positive result, as only part of the material would follow the oblique path, and in order to get the highest efficiency the oblique blades are placed at such a distance apart as to form a five-fold or five-threaded screw, so that practically every particle is forced forward in its appointed channel.

The conveyor is made in lengths of from 15 to 20 ft., and joined together with flanges. These are turned on the face and periphery, and are used at the same time as supports for the conveyor, resting on a series of pairs of rollers. The rollers are provided with flanges to prevent end movement. There is also a flexible packing ring between each pair of couplings, so that a slight variation from the straight line in the erection is not detrimental.

The driving pulley is made in halves, with a square opening to fit the square tube, and this can be attached at any point in the length of the conveyor most conveniently situated in relation to the driving power.

Conveyors of this design have been built and are successfully at work in lengths up to 250 ft. Fig. 64 shows such a conveyor in a cement works. As this tube conveyor is very rigid, it can also be used for transmitting a limited amount of power, so that at the extreme end, or in any desired position, power may be taken off by fixing a pulley, similar to the main driving pulley, concentrically on to the tube for driving small auxiliary conveyors or even elevators. This is sometimes of great convenience.

Fig. 64. Sues Conveyor, 250 ft. long, Conveying Fine Cement at Witkowitz, Austria.

Fig. 65 represents a perspective view and part section of such a conveyor, and Figs. 66 and 67 show cross and longitudinal sections of the same. The illustrations show a wooden tube with metal channels. *d* represents the oblique blades. *e e' e'' e'''* show the longitudinal channels in the four corners, as described above. The spaces *ff* can be covered over with sheet iron. *g* is the filling apparatus which revolves with the tube, and has lifters which scoop up the material fed into the fixed inlet *i* and deliver it into the conveyor tube. *k* and *k₁* show the slope at which the material is delivered into the tube. *b* are the ring supports to be used when further supports are desirable in addition to, or instead of, the flange coupling supports. These ring supports *b* are also employed in such positions where at times a portion of the conveyor has to be thrown out of work. For instance, if a conveyor of 100 ft. total length has to deliver for a

lengthy period at a point 50 ft. from the feed end, half the conveyor can be disconnected simply by taking the four bolts out of the nearest coupling, and in order to do so a ring *b* should be near to such a point to carry the tube ends. *c* are the rollers on which the ring *b* or the flange coupling are supported.

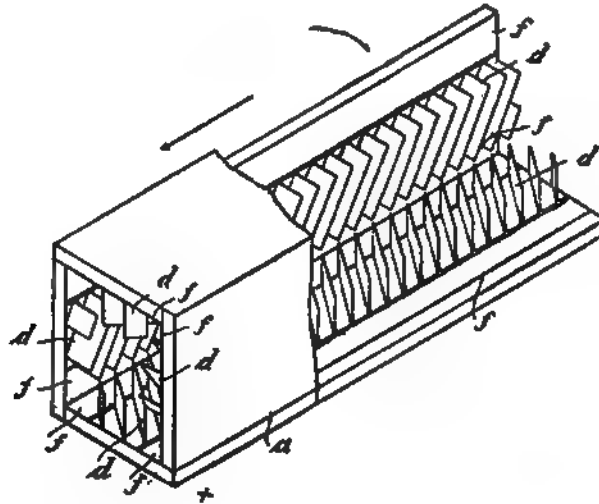


Fig. 65. Perspective View and Part Section of Sues Tube Conveyor.

A

d

B

Figs. 66 and 67. Cross and Longitudinal Sections of Sues Tube Conveyor.



Fig. 68. Open End Outlet.

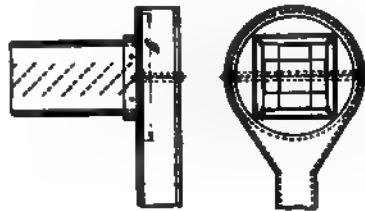


Fig. 69. Enclosed End Outlet.

The delivery at the opposite end can be either open, so that the material simply drops out, or it can be enclosed, which is preferable, to prevent dust. Such an enclosed end outlet, as well as intermediate inlets and outlets, are shown in Figs. 68, 69, 70, 71,

and 72. These intermediate inlets and outlets are easily understood from the illustrations, the former having four lifters which collect and deliver into the tube any material fed into the inlet, and yet when there is no material added at any of these intermediate inlets the flow of the material passing by is not obstructed.

The intermediate outlet is a little more complicated, as it contains a loose piece of the tube with its channels, which must be removed to make an outlet, but the change can be effected in a very few minutes. It will thus be seen that the Sues tube conveyor can be fed from any number of points, and that the material can be withdrawn at any



Fig. 70. Intermediate Inlet.

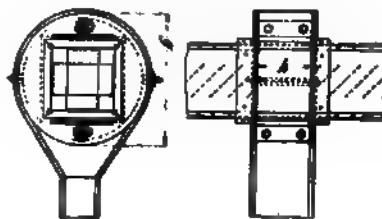


Fig. 71. Intermediate Outlet.

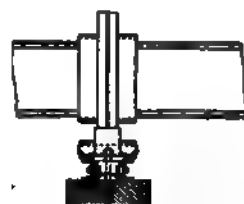


Fig. 72. Sues Tube Conveyor, showing Feed End.

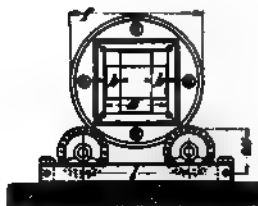


Fig. 73. End View.

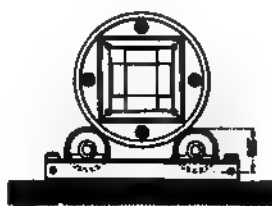


Fig. 74. Cross Section.

convenient point or points. It is therefore most useful, for instance, for feeding rows of silos or bins either one at a time or simultaneously.

Size Number.	a	b	c	d	e	f	g	h	i	k	l	m
1	7	13	23	20	7	20	20	6	18	7	16	6
2	9	23	3	20	7	20	20	8	20	7	16	6
3	12	3	33	24	8	24	24	10	24	8	24	7

The lettering of Figs. 68 to 74 correspond with the dimensions given in the table for Suesc conveyors of the three principal sizes in inches; the letter *c* in the table represents the pitch of the oblique blades, which stand at an angle of 45 degrees to the axis of the conveyor, and at an angle of 75 degrees to their base at the side of the tube.

The following table gives the capacity of the Suesc conveyor for the three sizes in tons per hour of Portland cement, at different speeds:—

TABLE GIVING CAPACITY OF SUESC TUBE CONVEYOR

Revolutions per Minute.	Capacity in Tons of Portland Cement per Hour.		
	No. 1.	No. 2.	No. 3.
10	1.2	3.4	8.37
15	2.04	7.2	12.555
20	2.88	9.	16.74
25	3.72	10.8	20.925
30	4.56	12.6	25.11
35	5.4	14.4	29.295
40	6.24	16.2	33.48
45	7.08	18.	...
50	7.92	19.8	...
55	8.76	...	...
60	9.6	...	...

ARCHIMEDES.

CONVEYORS

A.—APPLIANCES CONSISTING OF A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A CONTINUOUS PUSHING DEVICE—*continued*

CHAPTER V

PUSH-PLATE, SCRAPER, OR FLIGHT CONVEYORS

THE origin of the scraper conveyor may be found, like that of the worm conveyor, in the oldest industry of the world, namely, flour milling. It is rarely found now even in the oldest flour mills, but being the progenitor of an important conveyor, it may be interesting to give a few details as to its construction.

The box or trough was of wood, and sufficiently deep to carry the whole apparatus, including the return strand. The terminal pulleys were smaller than those of elevators of the same capacity, there being no lifting to perform. Their diameter varied from 10 to 15 in., and the belt which carried the wooden scrapers was rarely more than 2 or 3 in. wide, although the scrapers were from 6 to 10 in. long. The spindles were generally carried in bush bearings, fixed with a flange against the outer side of the box. A tightening gear was seldom used, but a large opening with a lid facilitated the tightening of the band, whilst in the base of the trough a piece of glass fixed flush with the inside of the box showed the miller when his conveyor was at work. The speed of the scrapers was from 100 to 200 ft. per minute.

Push-plate conveyors now vary very much in minor details of construction, but in principle they consist of a fixed open trough made of stout sheets of steel or iron, sometimes of cast iron, rarely of wood. The material to be conveyed is deposited in this trough, and is pushed or dragged along by a series of plates attached at equal intervals to an endless chain, which latter, with its attachments, travels over terminal pulleys, so that only one strand of the chain is at work. The chain or chains should be attached as nearly as possible to the centre of the push-plates. These are not usually allowed to touch the bottom of the trough, and are therefore fitted with skidder bars which slide on well-greased angle-bars forming portions of the framework. Sometimes instead of skidder bars the scrapers are fitted with a pair of small wheels or rollers running on corresponding channel or angle bars, which is a good plan, as it reduces the driving power required, and prevents the noise which in large and badly lubricated conveyors is often disagreeably loud.

The scrapers of push-plate conveyors are of different forms, the commonest being rectangular, though generally they conform as nearly as possible to the shape of the trough. They are sometimes, however, in the form of discs, rakes, or dogs, according to the material to be handled.

Fig. 75 illustrates two of the simplest types of scraper-conveyor made, the first being fitted with skidder bars, while in the second the push-plates are supported by rollers. Fig. 76 shows a general view of a push-plate conveyor of this latter type.

The trough is often made of two pieces of channel iron, with a renewable iron plate riveted or bolted underneath (see Fig. 77). The skidder bars of the leading strand of this conveyor run on slats of hard wood which are fastened to the channel irons, whilst the chain of the return strand runs over guide rollers. Sometimes the

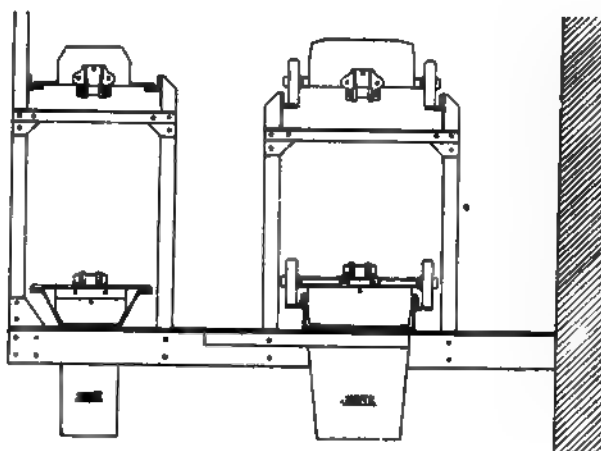


Fig. 75. Two Conveyors of the Simplest Push-Plate Type.

wooden slats are dispensed with, and the skidder bars allowed to run on the trough itself.

The U-link conveyor, illustrated in Fig. 78, has a trough similar to those already described, but generally of cast iron, but the pushing agent is altogether different. It consists of a large chain composed of U-shaped links of mild steel, between which, and on the top of which, the material is conveyed. The links are generally of a pitch equal

Fig. 76. Coal Bunkers Fed by Push-Plate Conveyor.

to their width, and are 3 to 4 in. deep by $\frac{1}{2}$ in. in thickness. The speed at which the chain travels is from 100 to 150 ft. per minute. The terminals are hexagonal, whilst

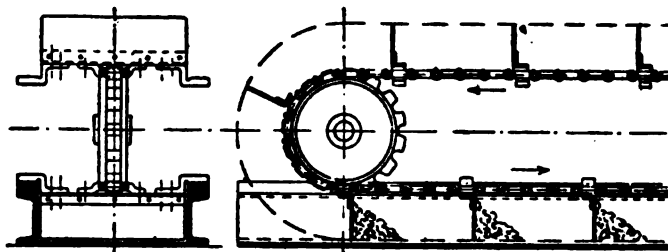


Fig. 77. Further Type of Push-Plate Conveyor.

the intermediate supports for the return strand consist of ordinary rollers which are about 6 in. in diameter, and sometimes 15 ft., and even 20 ft., apart. Openings are placed in the bottom of the trough at desired intervals, through which the coal can be withdrawn into the bunkers, or direct into the stoker hoppers. U-link conveyors may be inclined to a gradient of 30 degrees from the horizontal, and coal and coke may thus be raised to a suitable height for charging into the bunkers without the need of elevators.

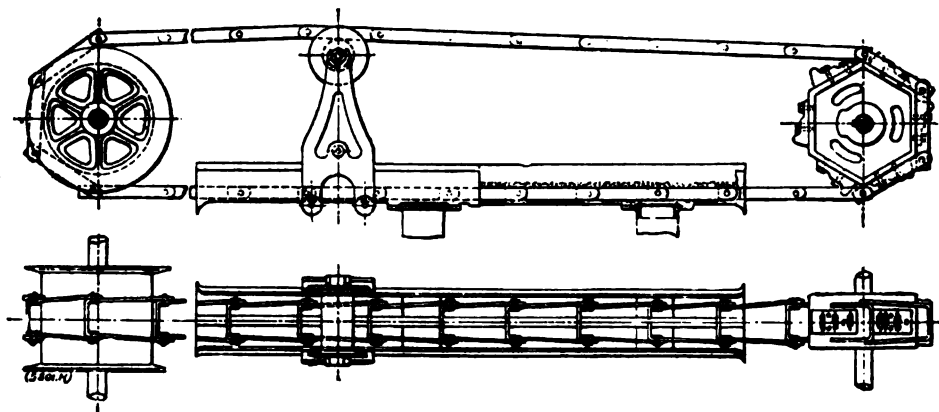


Fig. 78. U-Link Push-Plate Conveyor.

This type of conveyor is exceedingly strong, and on account of its simplicity and reliability is largely used in power houses for coal ashes and clinkers. The driving power required is small. Its design and construction enable erection and operation where it would be difficult to erect and operate a more complex plant.

The type illustrated is that of Ed. Bennis & Co., Ltd., used in connection with their power-house installations. The dimensions and capacities are as follows:—

Size of Trough.		Speed in Feet per Minute.	Capacity in Tons of Coal per Hour.
Width.	Depth.		
Inches.	Inches.		
9	5	18	40
12	7	18	60
15	8	18	80
24	12	18	140

The tensile strength of the link is from 28 to 32 tons to the square inch, with an elongation of 20 per cent. in 8 in.

A modification of the push-plate conveyor is the push-bar conveyor, generally used for handling hot coke, and which is more fully dealt with under Hot Coke Conveyors. Fig. 79 shows this type, as made by the Ewart Chain Belt Co., Ltd., of Derby.

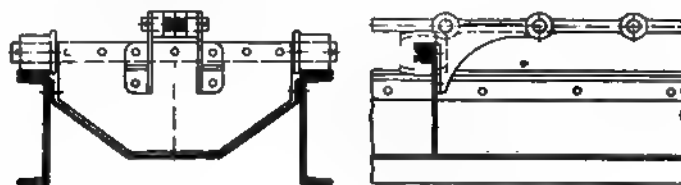


Fig. 79. Type of Push-Bar Conveyor.

Fig. 80 shows a form of push-plate or scraper conveyor known as the Monobar conveyor, made by the Link Belt Company, with a single bar between each two scrapers, or a few shorter ones joined up in the usual way, as shown in Figs. 81 and 82.

Figs. 83 and 84 show another type of push-plate conveyor, the design of the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft, its special feature being that in place of the push-plates the conveying chain supports frames which resemble small bottomless boxes, the base for these frames being supplied by the conveyor trough itself. At the sides of this conveyor trough, which is practically a smooth plate, are fixed channel irons in which the guide pulleys of the sections run. For the return-half of the conveyor an angle iron takes the place of the channel, the chain being composed of long links, which nevertheless run on a specially designed and constructed circular wheel instead of running over a polygon wheel, as is generally the case. Each link of the chain is fitted

Fig. 80. Monobar and Push-Plate Conveyor.

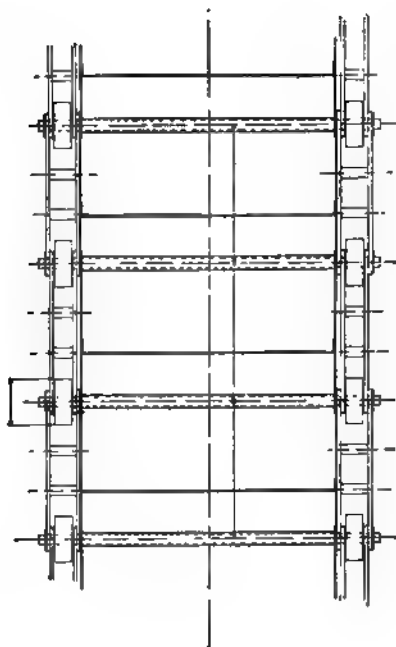


Figs. 81 and 82. Type of Push-Plate Conveyor.

with two studs—in addition to the two ordinary pins—which fit into suitable grooves in the two terminal wheels.

The advantage of this type of conveyor is that it can be used at a considerably steeper incline than an ordinary push-plate conveyor. A further advantage is, that there is no friction between the sides of the channel and the material being conveyed, the sides not being stationary, but travelling with the push-plates, as described.

1



Figs. 83 and 84. Push-Plate Conveyor with Travelling Sides.

For material of a non-cutting nature, such as wood chips, tan, peat, and other light goods, the usual order is sometimes reversed, and the chain fixed below the scrapers, running in a groove in the bottom of the trough. The push-plates in these cases are often made of hard wood.

Some forms of push-plate conveyors, *e.g.*, where the chain is attached in the centre of the plates, can be used for double service by directing the return strand through a second trough either above or below the original one. When sufficient headroom is not available the terminal wheels may be arranged horizontally instead of vertically, so as to have both strands in the same plane, and in this case also the conveyor may be made a double service machine by adding a second trough for the return strand. This construction is, however, confined to single chain conveyors. Such conveyors are used among other purposes for stock pile installations (see Dodge System of Stock Piles).

Ice Conveyors.—Scraper conveyors, or, perhaps more correctly, elevators for ice-houses, are used, particularly in America. They were perhaps more often used before

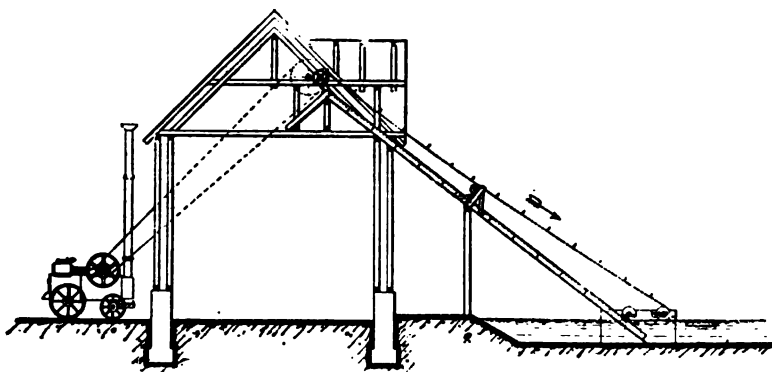


Fig. 85. Push-Plate Conveyor for Ice.

the introduction of refrigerators, but are still in general use in the vicinity of the Baltic Sea. These appliances very much resemble push-plates. The trough in which the ice slides up into the ice-house is made of wood, while the scraper plates are attached in the usual way to the chain, and drag the ice up the incline.

Fig. 85 shows a cross section through such an ice-house. The pieces of ice are floated into the lower end of the trough, where they are brought into contact with the plates, pushed up the inclined trough, and finally deposited in the store.

A long series of articles on the handling of ice, by Mr Howard B. Wood, in which up-to-date push-plate conveyors are employed, appeared in "Ice and Refrigeration," beginning in 1903, right up to 1913. The reader is referred to this series of articles, as the clemency of this country does not offer sufficient scope for such plant.

Capacity of Push-Plate Conveyors.—This depends on the size of the trough, and the pitch and speed of the plates. The pitch of the plates ranges from 18 to 36 in., and the speed of travel from 50 to 180 ft. per minute. For coke and other friable substances the speed should not exceed 50 to 100 ft. per minute, whilst in cases where the breakage of the material is of minor importance, the maximum speed of 180 ft. per minute may be employed.

For example, a conveyor with a trough 24 in. wide, having the plates 24 in. apart, and running at a speed of 100 ft. per minute, would convey 67 tons of coal per hour. A push-plate conveyor for coke with a 24-in. trough, and with malleable-iron plates

24 in. apart, running at 48 ft. per minute, would deliver about 20 tons of coke per hour.

TABLE GIVING APPROXIMATE CAPACITIES OF RECTANGULAR TROUGHED PUSH-PLATE CONVEYORS FOR COAL IN TONS PER HOUR AT A SPEED OF 100 FEET PER MINUTE

Width of Scraper.	Height of Scraper.	For Horizontal Conveyors. Pitch of Scraper Blades.			For Conveyors with Blades 24 in. pitch and inclined at		
Inches.	Inches.	16 in.	18 in.	24 in.	10°	20°	30°
10	4	17	15	11	9	7	5
12	4	22	19	14	12	9	6
12	5	26	23	17	14	11	8
15	5	35	31	23	20	16	11
18	6	...	40	30	25	20	15
18	8	...	60	45	36	28	24
20	8	...	...	52	42	33	28
24	8	...	...	67	60	48	36
24	10	...	...	86	75	60	45

Capacities for other speeds in proportion.

Power Required to Drive Push-Plate Conveyors.—This must depend on the nature of the material to be conveyed and on the condition of the trough. For instance, cement clinker and coke would take more power to convey than coal; but as this type of conveyor is altogether unsuited for hard and cutting substances on account of the great wear and tear, no examples are here given of a conveyor for such materials, the following figures being for coal conveying.

A push-plate conveyor, 100 ft. long, conveying coal at the rate of 50 tons per hour, will require a driving power of 12 H.P.

Timber Conveyors.—A conveyor on the same underlying principle, but of a much more substantial design, is frequently used in the lumber trade of North America. This conveyor will handle large baulks of timber. The chains of the conveyor are very strong, and are fitted at regular intervals with jagged or dog links, which lay hold of the timber or tree and drag it on a suitable support for long distances. The timber is often transported in rafts on the rivers, and the single stems are floated to an incline on the bank where these conveyors are erected, the lower terminal reaching sometimes a few yards below the water level. A man stands on the floating tree or trunk and directs one end on to the conveyor, which drags it out of the water direct to the saw-mills. Figs. 86 and 87 show two such conveyors, the former for light loads, the latter for logs up to 4 ft. in diameter.

Push-Plate Conveyors with Double Chains.—In this case the chains are attached to the two sides of the push-plates, preferably protected by being concealed in recesses in the sides of the trough. Such conveyors are to be recommended when it is desirable to have the trough unimpeded by chains above the plates. This form of construction has also the advantage that the chains are attached at a central position, which is most effective. Belonging to this category is the hot coke conveyor (Fig. 79, also see Chapter on Hot Coke Conveyors), the plates of which are sometimes in the form of rakes, and sometimes in the form of plain iron bars. This latter design is quite admissible for coke when in large pieces, and therefore as efficiently pushed by a bar as by a plate, whilst the rake is more substantial, and therefore resists the action of the

hot coke better than a plate which offers a larger surface to the damaging effect of this material.

Cable Trough Conveyors.—These differ from those previously described, in that the pulling or pushing element is a cable instead of one or more chains, and that the iron or steel disc attachments which propel the material have no additional support, such as skidder bars or rollers, the trough forming the only support.

The trough is either V or U shaped, and generally of wood lined with sheet iron, or of iron plates only, according to the nature of the material to be conveyed.

The wire rope is generally 1 in. diameter, and the disc flights are of cast iron, in halves, and are clamped on to the cable with bolts. The coupling generally used is

Figs. 86 and 87. Timber Conveyors.

of the same design as the ordinary disc flight shown in Figs. 88 and 89, the ends of the rope being lapped and passed through the clamp, with the ends of the rope diverted



Fig. 88. Type of Cable Trough Conveyor with V-shaped Trough.

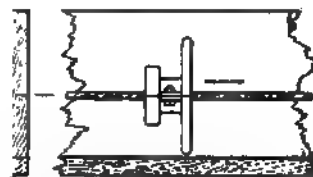


Fig. 89. Type of Cable Trough Conveyor with U-shaped Trough.

to either side so as to fit the gaps of the sprocket wheel. This kind of conveyor is suitable for handling light and bulky material, preferably in a straight line and down an incline. It is well adapted for handling timber, blocks, chips and shavings, peat, pulp, hay, etc., but is also sometimes used for heavier materials.

The speed of travel is 100 to 120 ft. per minute. Figs. 88 and 89 give two longitudinal and two cross sections of two forms of trough cable conveyors.

Fig. 90 illustrates complete installation of this type of conveyor, showing the two terminals in plan and elevation, as well as a cross section through the conveyor.

Fig. 91 shows this type of conveyor fitted with metal troughing. It also illustrates the manner in which two such conveyors are driven at right angles.

The method of feeding and withdrawing the material at intermediate points is simple with this conveyor. The former presents no difficulty, as the trough is open, and

can therefore receive the feed at any point. The latter is effected by means of outlet slides at any point, for a flat-bottomed trough; for a V-shaped trough, flap doors hinged

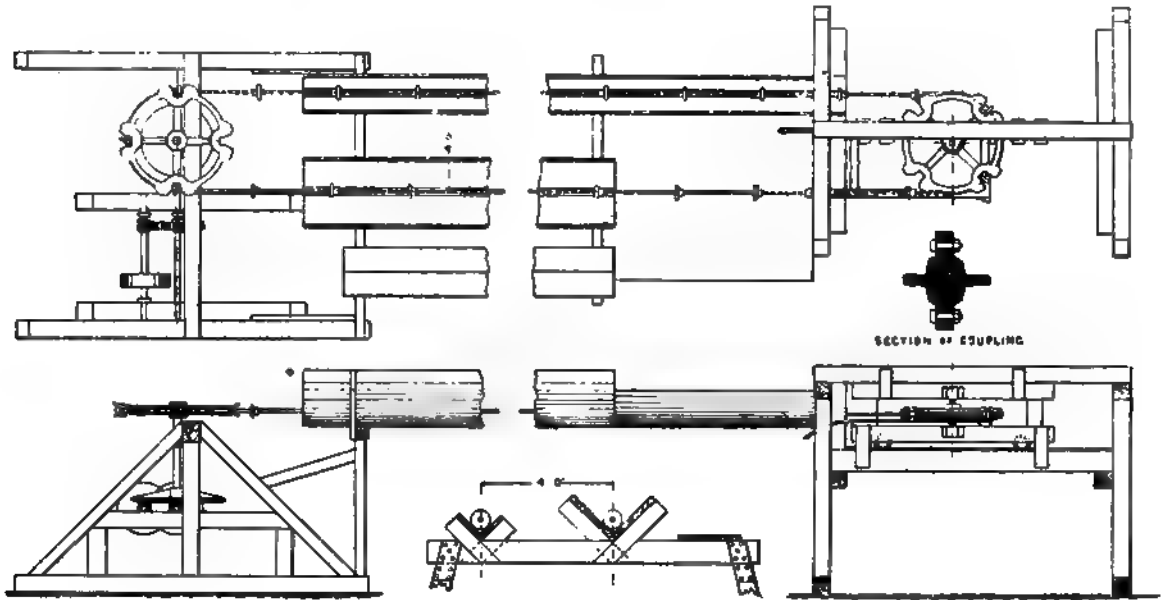


Fig. 90. Complete Installation of Cable Trough Conveyor.

on either side, forming a V shape when closed; and for troughs with a semicircular base, hinged flaps of the same semicircular form are employed, which are so arranged

Fig. 91. Angle Station of Cable Trough Conveyor.

shoot for the material as it leaves the conveyor. With these outlets action necessary is to provide a central support for the conveying discs let is open, to prevent them catching, as this would result in a break.

The horse power consumed by these conveyors cannot be given, as they are mostly used on a downward gradient, when they may even produce power. If on a level or slightly downward incline, the power consumed is about the same as for ordinary scraper conveyors of the same capacity.

Cable Trough Conveyor of the Jeffrey Manufacturing Co.—Cable trough conveyors may also be used as inclined retarding conveyors for lowering coal from higher to lower levels, work which, as a rule, is performed by means of a system of colliery tubs. The plant here illustrated (Fig. 92) is of special interest, because it replaces the old tram system, and has several points of advantage in its favour. Its first cost is less, while it is simple and requires practically no power or attendance. In the plant illustrated the coal is discharged over the ordinary tippler at the head into a hopper, from which it is fed on to the conveyor, which in this case is a Jeffrey wire rope with disc-shaped attachments running over special sheaves at the terminals and operating in a V-shaped trough. When the conveyor is loaded and working with a continuous feed, it acts as a retarder in keeping the coal from running away by itself. A small motor is generally necessary to start the conveyor, while when running with a full feed a brake is used to keep it in check. By this system coal may be carried to the shoots or cars below with but little breakage, and at the rate of 100 to 140 tons per hour. In the plant illustrated, the distance from the upper to the lower level is 500 ft. Formerly colliery tubs were used, but as this

Fig. 92. Retarding Cable Trough Conveyor at the Mines of the Logan Consolidated Coal and Coke Co., Matewan, W. Va., U.S.A.

Fig. 93. General View of Meat Conveyor.

system has proved a practical success in America, it will doubtless find favour in other countries for work under similar conditions. This plant was erected by the Jeffrey Manufacturing Co., of Columbus, U.S.A., for the mines of the Logan Consolidated Coal and Coke Co., at Matewan, W. Va., U.S.A.

Slaughter-House Conveyors.—A modification of this type of conveyor is used for handling carcasses in slaughter-houses when the trough is dispensed with altogether. A general view of such an appliance is shown in Fig. 93, whilst Fig. 94 shows the detail

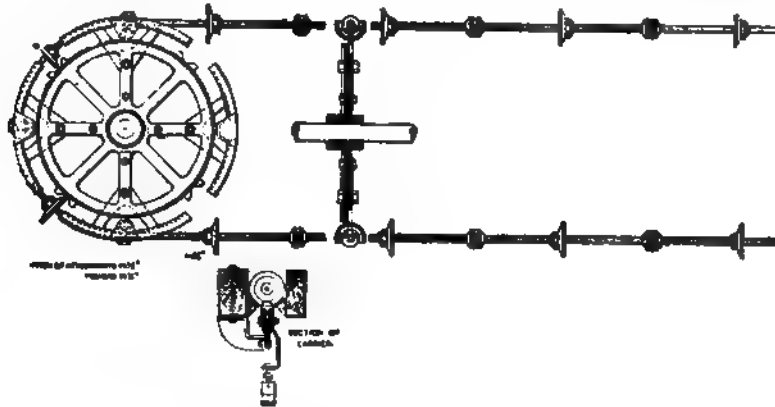


Fig. 94. Details of Meat Conveyor.

of one of the driving terminals, and the construction of the conveyor itself. It consists of a steel cable to which are connected at regular intervals two kinds of attachments, the smaller one being for the purpose of driving the rope from the terminal, whilst the larger and disc-shaped attachment is intended to engage and push forward the trolleys from which the beef and pork are suspended.

The illustrations explain themselves. Such a plant is at work at the packing house of John P. Squires & Co., Cambridge, Massachusetts, U.S.A., and was erected by the Steel Cable Engineering Co., Boston, U.S.A.

CONVEYORS

B.—APPLIANCES WITH A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A RECIPROCATING PUSHING DEVICE

CHAPTER VI

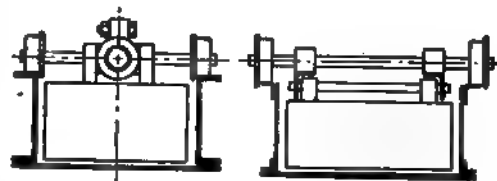
PUSH-TROUGH CONVEYORS

THE construction of these appliances is similar to that of the push-plate conveyor, the principal difference being that instead of an endless chain of push-plates revolving over the trough, a rod or frame is substituted, which carries hinged push-plates. This rod or frame

Fig. 95. Push-Trough Conveyor with Outlet.

has a reciprocating movement, so that the plates act like push-plates in the forward movement, while they disengage, and, being hinged, slide over the top of the material at the backward stroke. Fig. 95 shows such a conveyor of the most usual design. The trough is generally made similar to that of the push-plate, *i.e.*, with two \sqsubset irons, and a plate at the bottom riveted to the under flange of the two \sqsubset irons.

The reciprocating rod or frame is carried at intervals by pairs of rollers, which revolve on the upper flange of the \sqsubset iron trough. The two usual methods of



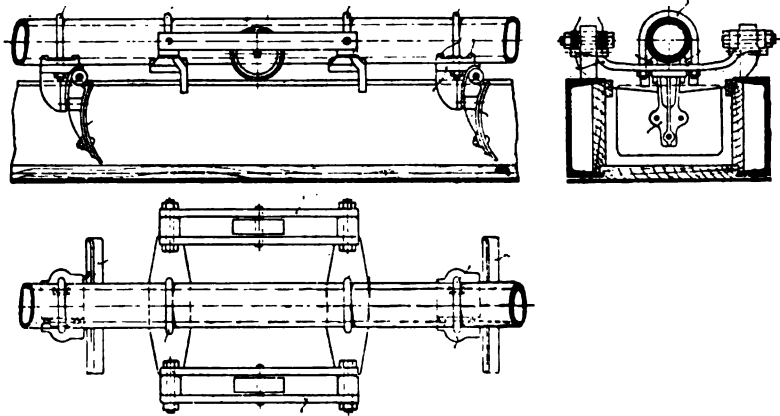
Figs. 96 and 97. Methods of Hinging the Push-Plates.

hinging the spades or push-plates are shown in Figs. 96 and 97. The oscillation is given to the rod or frame with its hinged blades by a crank and connecting rod, as shown in Fig. 95, which represents the pipe construction. An outlet manipulated by a chain-wheel, rack, and pinion is also indicated upon the drawing. The dotted circles represent the electro-motor and countershaft:

The push-plates are 18 to 30 in. apart, the stroke is equal to the pitch of the blades, and the speed 50 to 60 strokes per minute.

The capacity is the same as for push-plate conveyors of the same dimensions, etc.

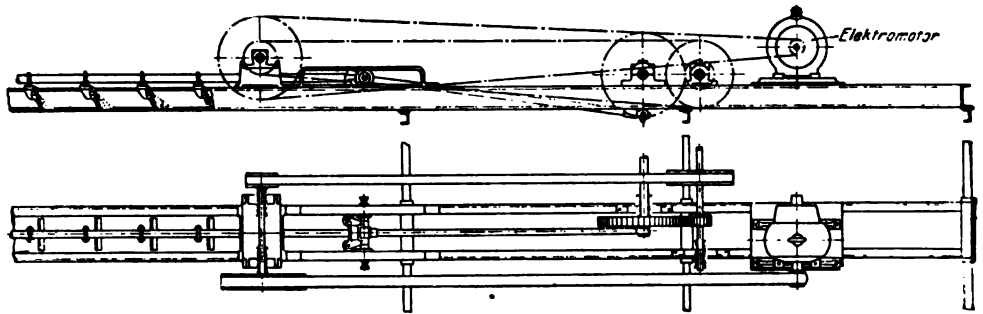
Push-trough conveyors have a restricted use, as the blades will not readily engage with large material. They are principally used in foundries to convey foundry sand.



Figs. 98, 99, and 100. Push-Trough Conveyor for Foundry Sand.

They will also handle all other fine materials, as well as ashes and small coal to the size of nuts, ordinary sand, gravel, etc.

Figs. 98, 99, and 100 illustrate a similar conveyor, several of which are at work on foundry sand in a large German foundry, and made by Vereinigte Schmirgel und Maschinen-Fabriken, Hanover-Hainholz.¹ The description of the previous illustration will make a



Figs. 101 and 102. Showing Motor and Method of Reducing Speed.

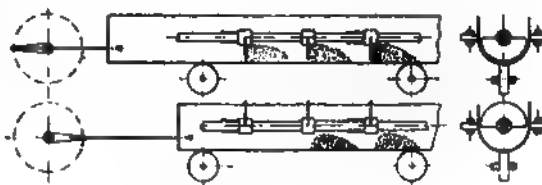
repetition unnecessary, and it may suffice to say that this conveyor is nearly 100 ft. long. Figs. 101 and 102 show the motor and the mode of speed reduction. The principal feature of the construction is the curved form of the blades, and the differential roller supports for the reciprocating device. For the latter it is claimed that the power consumption is reduced.

It has been found that the wear is greatly reduced by lining the trough with wood, which material is less affected by the foundry sand than iron.

¹ *Zeitschrift des Vereines deutscher Ingenieure*, 1909, page 1225.

This type of conveyor is also used in the United States for handling salt from grainers. The trough is there made of hard maple wood, and the base sometimes lined with crude $\frac{1}{2}$ -in. plate glass. The reciprocating motion is slow, and obtained either by a connecting rod and crank similar to those already described, or by an hydraulic cylinder. The stroke is 5 ft. and the feathering blades 24 by 6 by $\frac{1}{8}$ in., placed 3 ft. pitch, and heavily galvanised. These conveyors are frequently 200 ft. long, and it is believed that when the base is lined with glass they may safely be made 300 ft. long. Such conveyors have been at work for four years handling the salt from sixteen grainers, each 176 ft. long by 13 ft. wide; they are but little used in this country.

There is a further type of conveyor which, though differing from the foregoing, ought to be dealt with under the same heading. It is built on the Commichau principle, in which case the trough oscillates as well as the plates. This conveyor is illustrated in Figs. 103 and 104, which show it in its extreme forward and its extreme backward position. The upper drawing shows the trough on the point of starting the forward movement, pushing the material forward by means of plates attached to the longitudinal rod.



Figs. 103 and 104. Push-Plate Conveyor on the Commichau Principle.

The lower illustration gives the conveyor ready for its backward movement, the plates having been turned upward through a turning motion of 180 degrees of the spindle instead of being hinged as in the former case.

It is only in short conveyors that the trough receives a backward and forward motion. In the case of greater lengths the spindle with its plates performs the backward and forward as well as the turning motion, while the trough remains stationary. Conveyors of this type are said to have been built for considerable lengths, but they appear to be more generally used for short lengths. It is said that a trough 12 in. wide will convey 50 tons of coal per hour.

It is claimed for this appliance that it is more suitable than worm conveyors for handling material of a sticky nature.

CONVEYORS

C.—APPLIANCES IN WHICH THE TROUGH CONTAINING THE MATERIAL MOVES BODILY WITH THE MATERIAL

CHAPTER VII

BAND CONVEYORS

Historical and Introductory.—The credit of this invention is due to the late Mr Percy Buchanan Graham Westmacott, who in 1868 carried out a series of experiments in order to determine what type of conveyor was most suitable for the mechanical handling of grain for the new granaries of the Mersey Dock and Harbour Board. The experiments were initiated on worm conveyors of different types, which, however, proved altogether inadequate for large granaries and silo warehouses, principally on account of their small capacity and the great driving power required. He then began to experiment with endless travelling bands, and after a few preliminary trials with small canvas bands, made further trials with a band 12 in. broad. This band was run at different speeds to ascertain the highest velocity at which such conveyors could be worked with safety and economy. It was also desired to practically test the most suitable speeds for different kinds of grain.

A speed of 8 ft. per second was found to be the maximum for light grain, such as oats, while careful experiments showed that even bran and flour could be conveyed at this speed without such material being thrown off the band by the resistance of the air to its passage. A speed of about 9 ft. per second was found suitable for heavier grain, such as Indian corn, peas, etc. The capacity of this 12-in. band when fed to its fullest extent was found to be about 35 tons of grain per hour, the band then travelling at the speed of 8 ft. per second.¹

It was, moreover, found that grain had no tendency to fall off the band, and that even single grains when placed near the edge remained in position while passing over the carrying rolls at the speeds mentioned.

While Mr Westmacott's invention left the band conveyor an undoubted success, the efforts of those who in the early days tried to improve upon it, were doomed to failure. They feared that a flat band would spill the grain, and the supporting rolls were therefore hollowed out in the middle to give the band the form of a trough. This was all right as far as conveying was concerned; but, on the other hand, the bands employed, which were composed of cotton webbing covered with rubber, wore out in a very short time, because, owing to the varying diameters of the curved roller and the consequent variation of the circumferential velocity at different points of the roller, a grinding action was set up between the rollers and the band, the velocity of the latter being of course the same for the whole of its width. This grinding action destroyed the bands. Experience proved that Mr Westmacott's flat band was all that was necessary for conveying grain,

¹ *Proceedings Mech. Eng.*, August 1889.

which can be conveyed in all security on a perfectly level band, provided it is properly delivered thereon, *i.e.*, at the same speed as that at which the band is travelling. Band conveyors for grain often run perfectly flat, except at the point or points where grain is fed to them; but at these points two separate cylindrical curving rolls are applied, which slightly hollow the band for a few feet, and then allow it to lie flat again on its supporting rollers.

These endless bands run over terminal pulleys, and are in addition supported on their way by a series of rollers, which are more frequent on the loaded than on the empty strand. Such conveyors are usually fitted with some kind of tightening gear to keep the belt in tension.

Supporting rollers are fitted at intervals of 6 ft. to the upper or working strand of the band, and at every 12 ft. on the lower or return strand. Sometimes it is desirable to use both strands of the band for conveying purposes, thus making it a double service machine, in which case the supporting rolls for the lower strand must be as close together as for the top. In such a case the terminal pulleys should be larger than usual in order to give the two strands a greater distance from each other, to allow sufficient

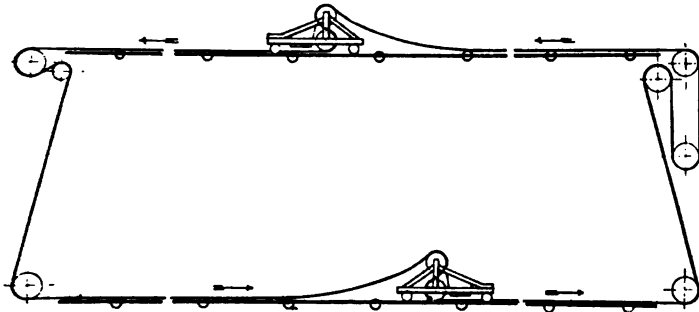


Fig. 105. Band Conveyor suitable for Conveying on Both Strands.

space between the strands to conduct the grain to the lower band, and discharge it again before reaching the other terminal. The two strands can be run any distance apart by using two additional guide pulleys for the terminals, as shown in Fig. 105. In such a case one band might run along the top floor of the granary whilst the other travelled along the bottom. Throw-off carriages are indicated on both top and bottom bands.

The tightening of a band conveyor is effected in a similar manner to that of tightening elevator bands,¹ *i.e.*, by means of two screws which push or pull the two pedestals of one terminal pulley further away from the other terminal; but as such an appliance does not admit of great latitude, it is insufficient for very long conveyors. In such cases the tightening gear would consist of a pulley, held in tension by weights, over which the belt passes. This tightening pulley can be placed at any point on the return strand of the belt, but is generally situated at the end opposite to the driving end of the conveyor.

A tightening pulley as used at the terminal is shown in Fig. 106.

Another form of tightening pulley which can be applied to any part of the returning band is shown in Fig. 107.

It is undoubtedly preferable to use tension screws for tightening the band if it be possible, and in cases where throw-off carriages with fixed pulleys are used, and where

¹ See Tightening Gears.

the conveyor is not too long, there is no objection to this course; but if throw-off carriages of the swivelling type are used, as in the case where the material has to flow on the band past the throw-off carriage, it becomes necessary to have tightening gears with weighted pulleys. As to the allowance to be made for tightening belts, that must greatly depend on the quality of the band. A good conveying band, with a breaking strain of say 400 lb. per ply per inch width, requires an allowance for tightening of 4 per cent. This

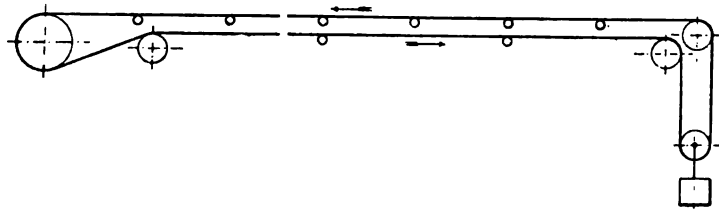


Fig. 106. Mode of Tightening Band Conveyor at Terminal.

would indicate that with a band of good quality even of great length the screw tightening gear can be employed if otherwise suitable.

Where permissible, belt conveyors should always be erected sufficiently high above the floor, so that any accumulation of material which may be spilled, or, in the case of fine powders, that may be carried back by the return strand, cannot interfere with the rollers

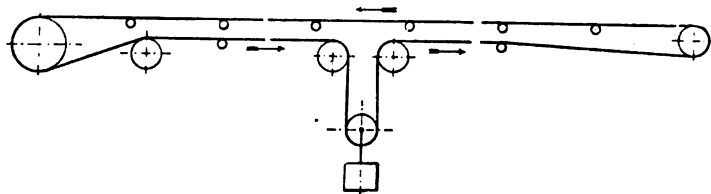


Fig. 107. Mode of Tightening Band Conveyor on any Part of Return Strand.

by coming into contact with them. A sufficient space under the return half of the belt also makes it more convenient to clear up any such accumulations at intervals.

To withdraw the feed from a band conveyor at any intermediate point, a throw-off carriage is employed, and the credit for the invention of this device is due to the

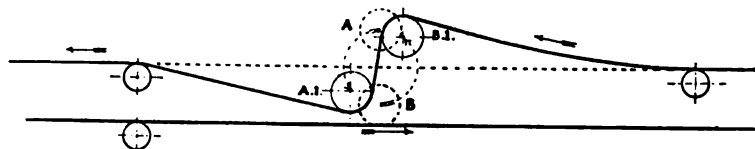


Fig. 108. Diagrammatic View of Throw-off Carriage.

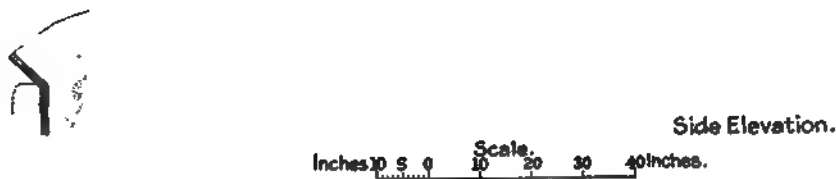
experiments of Mr Westmacott. To remove the grain he made trials with several contrivances, including air blast and brush devices driven from the band itself. Both methods, however, gave but indifferent success. In both cases a most objectionable amount of dust was raised. Moreover, the friction of the brushes on the band proved in time injurious to the latter. The idea then occurred of diverting the stream of grain by means of an upward deflection of the carrying band, thus casting the grain clear of the band and into the air for a short distance, so that it could in falling be caught and led off through a spout on either side as required. The device consists in principle of two guide pulleys which in most

cases can be turned round a common centre by means of worm and worm wheel. When out of use one guide pulley is above and one below the band, which runs through between them but without touching them. If delivery of the material is required at a certain point, the throw-off carriage is pushed into position and the guide pulleys are turned round the common centre in the direction of the arrow, so as to raise one part and lower the other part of the band as shown in Fig. 108. In this illustration the dotted circles A, B indicate the guide pulleys when out of use, while those in full line A₁, B₁ show the position of the pulleys when the throw-off carriage is in use.

As soon as the grain arrives at the throw-off carriage, it leaves the band by its own momentum, and is received in a hopper which forms part of the apparatus. It is then spouted sideways to its destination clear of the band.

This arrangement for withdrawing the grain from the band proved a complete success, and has been universally adopted. The throw-off carriage, designed for the use of the Liverpool Docks in 1868, was the first of these devices, and is shown in Figs. 109 and 110.

It consists of a pair of wrought-iron rollers centred in gun-metal bearings in a



Figs. 109 and 110. Adjustable Throw-off Carriage Designed for the Liverpool Docks.

rocking frame, which is hung in a movable carriage running upon the top of the timbers of the wooden framing that supports the travelling band. The carriage is moved to any position along the length of the band where the grain is required to be discharged, and is there secured by wedges and clamping screws.

The rocking frame is rotated in either direction, by means of worm and worm wheel, to bring the pair of rollers into action in the proper position for throwing the grain off in the same direction as that in which the band is running, while the rollers are turned back into a horizontal position to be clear of the band when the carriage is required to be moved to any other point on the length of the band. A curved spout is attached to the carriage for receiving the stream of grain in its fall and leading it off on either side of the band.

The throw-off carriage shown in Fig. 111 is of a very simple kind without adjustment. It has a clamp by means of which it can be secured in its position. The diagram shows also the receptacle for the grain and the alternate outlets on either side with valve arrangements.

This appliance having no means of adjustment, when not in use must always be moved to the terminus. It is also sometimes made with a third outlet, which delivers

the grain back again on to the band if intermediate delivery is not required. In such a case the position of the carriage when not in use is immaterial, as the grain can proceed through this third outlet uninterrupted.

Band conveyors can be fed without any difficulty; but it has been found necessary to slide the grain upon them from the feeding hopper through a shoot rather less than half the breadth of the band and set at an incline of $42\frac{1}{2}$ degrees to the horizontal, to give the grain falling upon the band a horizontal velocity nearly equal to that of the band.

It is very important to regulate the feed of the band, if only to minimise wear as much as possible, especially when conveying coal and sharp-edged material. The material should not strike the band vertically, whilst the height from which it falls must be reduced as much as possible to allow of a gentle drop.

As the flow by gravity of grain of various kinds and in varying condition through a spout differs considerably, it is advisable to place a pair of oblique side rollers at the point where the grain falls upon the band as already mentioned, for the purpose of preventing the tendency of the grain to spread. In passing heavy quantities of grain along the band for a considerable distance it has also been found expedient to apply

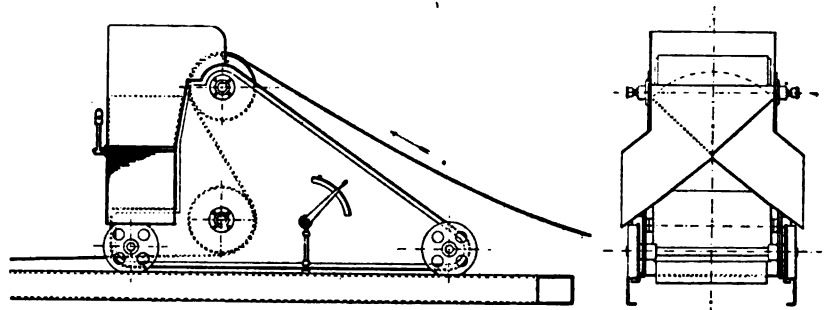


Fig. 111. Non-adjustable Type of Throw-off Carriage.

at intervals pairs of these oblique side rollers, which are carried in movable frames which can be set at any required spot.

All conveyors which are intended for intermediate delivery by means of an adjustable throw-off carriage must be fitted with tightening gears, as shown in Figs. 106 and 107, because the use of such throw-off carriages necessitates additional length of conveyor band, which must be disposed of whenever the carriage is out of use. These tightening arrangements provide suitable accommodation for such extra length of band.

As there is sometimes a tendency for the band to make a side movement on its rollers, so that the centre of the band is not in the centre of its supports, the employment of one or more pairs of small rollers placed against the edge of the belt is sometimes resorted to to prevent this, but this should not be necessary if the belt is well made, and if the idlers are all parallel and true.

Belt conveyors require no particularly rigid structure, and are therefore very suitable for temporary work, provided that the conveyor is of itself suitable for the work.

The belt conveyor is now a very popular means of conveying both heavy and light materials. When first introduced, about 1868, by the late Mr Percy B. Westmacott, it was used for conveying cereals and seeds only, but between the years 1885 and 1890 a number of more or less experimental plants were erected for minerals, and the credit for introducing a satisfactory band for such materials is principally due to Mr Thomas Robins.

At the present day thousands of installations are successfully at work, handling almost all kinds of material, hot and sticky substances being almost the only ones for which this method of transportation is unsuited.

The accompanying illustration, Fig. 112, represents a form of band conveyor constructed by the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft for conveying coal. The illustration shows clearly the type of tightening gear employed. It also gives the main drive with its two tightening pulleys in plan and elevation, the throw-off carriage, and a cross section through one of the termini, as well as one intermediate section through the band.

The difference in construction between conveyors for grain and minerals consists chiefly in the quality of the band and the form of the supporting idlers, and whereas for grain curving rollers are only occasionally used, conveyors for minerals are fitted with curving rolls for the entire length of the loaded strand, forming it into a continuous trough.

The following is a more detailed description of the principal parts constituting a modern band conveyor:—

The Belt.—The most important part of a belt conveyor is undoubtedly the belt. Stitched canvas or woven cotton belts are often used, particularly for small installations, on account of the comparatively small first cost. They are usually saturated with some oily substance, the better to withstand the influence of the weather. Balata, and even woven wire bands are used at times, but for first-class work of a permanent character there is nothing to equal a good composite cotton rubber belt.

Rubber belts are composed of a foundation of cotton duck covered with rubber solution or “friction” pressed together, and the whole is then enclosed in a rubber covering, which may be rather thicker on the carrying side. The belt thus produced is then stretched and finally vulcanised.

Exhaustive experiments have been made by Mr Thos. Robins to ascertain the best class of rubber coverings to use for conveyor belts. Pure rubber is, no doubt, the most serviceable material, as it is almost indestructible, and as the rubber suffers very little wear from contact, even with sharp and cutting materials; but as pure rubber is exceedingly costly, it is practically beyond the reach of ordinary users, and the experiments alluded to were made to ascertain what kind of admixture to the rubber will deteriorate its wearing qualities least.

It is interesting to find from these tests that even steel wears faster than rubber under a heavy sand blast, and under conditions to which a belt would be exposed when handling minerals. The following table and diagram (Fig. 113) show the wear on the different materials subjected to a uniform sand blast for forty-five minutes:—

Rubber belt - - - -	1'0	Woven cotton belt, high grade - -	6'5
Rolled steel - - - -	1'5	Stitched duck, high grade - -	8'0
Cast iron - - - -	3'5	Woven cotton belt, low grade - -	9'0
Balata belt, including gum cover -	5'0		

The object of the rubber covering is two-fold. The thicker covering on the upper side is to resist abrasion, and the remainder of the cover is for the purpose of protecting the body of the belt from moisture. Since the rubber solution, forming the “friction” with which the duck is held together, is not absorbed sufficiently by the fibres of the cotton duck to make the body of the belt waterproof, and as the cotton, where exposed, absorbs moisture as readily as the wick of a lamp, it is most important that the outer covering should be perfect, particularly if the belt is exposed to the weather.

It is also necessary to see that the belt does not in any way rub against any hard

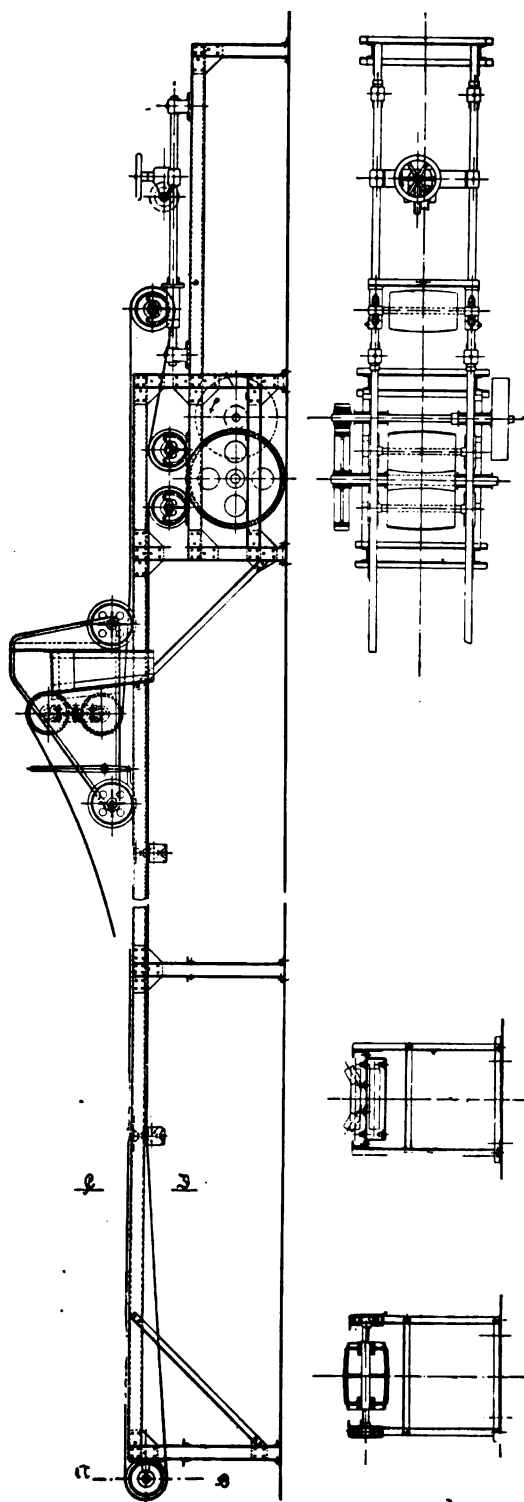


Fig. 112. Coal Conveying Plant of the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft.

substances, as any abrasion or cut in the covering, sufficiently deep to admit the moisture to the cotton, may cause serious damage to the belt, as the rubber loosens its hold on the damp cotton, forming blisters, which soon elongate along the belt through the compression and expansion of the inner parts when passing over the terminals.

The number of plies of duck of which the belt is composed must be such as to make the belt sufficiently rigid to support the maximum load between the supporting idlers without sagging. This is the only condition which need be observed for ordinary conveyors of medium lengths. According to Mr C. K. Baldwin, of Chicago, the number of plies should be as follows: belts of 12 to 14 in. wide should be not less than three ply; belts 16 to 20 in. wide not less than four ply; belts 22 to 28 in. not less than five ply; while not less than six ply should be used for belts from 30 to 36 in. in width.

For extra long conveyors, however, and in cases where one or more additional belts or other machinery are to be driven from the end terminal of a conveyor, the tensile strength of the belt has to be taken into consideration, and the belt so constructed that the tension is not more than 20 to 25 lb. per inch per ply, although a good belt should have a breaking strain of about 400 lb. per ply per inch. The Robins type of belt is made with a flexible central portion by stopping off some of the plies of duck at varying distances from the edge, and by

substituting a thicker layer of india-rubber to make up for the missing duck. This not only makes the belt conform more readily to the troughing shape of the idlers, but the thicker layer of rubber also resists the wear and tear which naturally comes in the middle of the belt, whilst the stiffer edges of the belt support the trough between the idlers, and give it the necessary tensile strength.

Some very interesting tests have been conducted by Mr Edwin J. Haddock, of Columbus—the results of which appear in the *Proceedings of the American Society of Mechanical Engineers*—as to the behaviour of conveyor belts under tension, more particularly to ascertain the effect of initial tension on the tractive force of conveyor belts on the driving drum.

The driving terminal used for the test consisted of a drum 42 in. diameter, with the snubbing idlers so arranged as to give a belt contact of 180°, the tail terminal being so arranged as to exercise a variable tension in a horizontal direction by means of a rope running over a pulley to receive a weight.

The weights suspended were as shown in the following table, and the experiments were made in the order given:—

TABLE SHOWING THE EFFECT OF DIFFERENT TENSIONS ON THE SAME
TERMINAL OF A BELT CONVEYOR

Tension Weight.	Initial Belt Tension.	Amperes.	Effective Pull on Belt.	Belt Strain.	
				Maximum.	Minimum.
650	325	14·0	260	455	195
800	400	16·5	330	565	235
1,300	650	24·0	550	925	375
1,500	750	29·0	690	1,095	405
2,000	1,000	38·0	650	1,475	525
1,500	750	31·0	750	1,125	375
1,250	625	25·0	575	913	337
1,000	500	22·0	490	745	255
750	375	18·0	370	560	190
3,000	1,500	56·0	1,450	2,225	775

NOTE.—The weights are given in lbs.

Beginning with a weight of 650 lb. and gradually increasing to 1,500 lb., the belt stretched but slightly, but under the additional 500 lb. with a total of 2,000 lb. the belt elongated about 3 ft. in its total length of 158 ft. The belt then remained without further stretching whilst running under the weight. On removing the load gradually to 750 lb., the belt recovered 15 in. of the stretch; while under a load of 3,000 lb. it stretched 3 ft. 8 in., or 8 in. more than under the 2,000 lb. load. The belt was then run under the 3,000 lb. load for thirty minutes without changing its length appreciably.

The belt strain caused by the application of the last weight being 1,500, is equivalent to a stress of 31.25 lb. per inch per ply. The belt being 12 in. wide and four ply, this is not far short of the manufacturer's guarantee of 40 lb. per inch per ply as the ultimate working strength of rubber-covered cotton duck belting.

The best method of joining conveyor belts is by butt joint with ordinary belt fasteners.

Conveyor belts will last longer if they are not strained over rollers or terminals which are too small, if not troughed too deeply, and if the troughing rollers are kept away from the terminals at least a distance of six times the width of the belt.

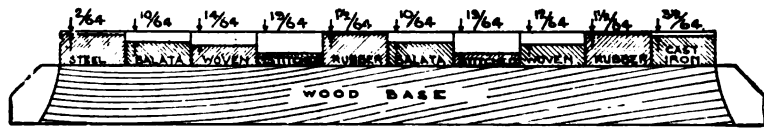


Fig. 113. Diagram showing Amount of Wear of Various Materials after being subject to an Equal Abrasion.

It may be noted that bands made of woven wire are sometimes used in connection with coal-washing plants. As these bands have much in common with belts of textile material, they may be handled in much the same way, and run at a high speed, nearly 10 ft. per second. To ensure a proper grip, the driving terminals must be faced with rubber, leather, or lagged with wood. Such bands are not very durable, their ten-



Fig. 114. Supporting Roller for Grain Conveyor.

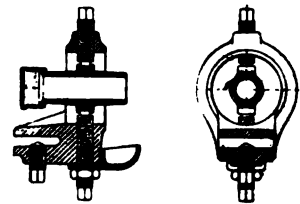


Fig. 115. Idler Roller Bearing for Band Conveyor.

dency to stretching and their relatively high price being against their more frequent adoption; owing to the shortage of rubber and cotton during the war, they have, however, been largely used.

Troughing of the Belt.—Not many belt conveyors are used at the present time with flat belts, on account of the larger capacity of troughed conveyors. The ordinary conveyor belt, with uniform plies of duck across the whole surface, is naturally stiff, and, if forced to assume the shape of a deep trough, is bound to suffer, as the adherence between the plies of duck and the rubber coating is strained and distorted by the ever-repeated process of bending. This type of belt, if otherwise suitable for the material to be conveyed, should never be bent more than into a shallow trough.

For deep troughing the type of belt advocated by Robins is most advantageous, as such a belt can stand the strain of being continually shaped into a deep trough, having a natural tendency to do so, as the sides are stiffer than the middle.

Idlers.—A supporting roller or idler for a grain conveyor is shown in Fig. 114.

These supporting rollers are 4 to 6 in. in diameter, and are sometimes made of wood, but more often consist of steel tubes to which spindles with conical end gudgeons are secured. These gudgeons generally run in suitable bush bearings, which should be well lubricated.

A more elaborate bearing is the one illustrated in Fig. 115. It consists of a neat cast-iron bracket which can be clamped to the angle-iron framework of the band conveyor without necessitating the drilling of holes in the same. The bearing is adjustable up and down, while one end is formed into a Stauffer lubricator, which can be filled with a viscous lubricant. This bearing being long and movable, will adjust itself to the position of the spindle, so that friction should be reduced to a minimum. The appliance is also fitted with a removable cup for the reception of any surplus lubricant.

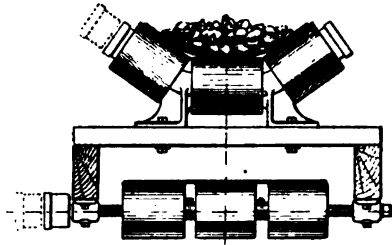


Fig. 115A. Support for Band Conveyor of the Robins Conveying Belt Co.

Sometimes curving rollers are used at intervals in addition to the point or points where the conveyor receives its feed. The type most generally in use is that illustrated in Fig. 115A, and a modification of the same principle for wider belts, shown in Figs. 116, 117, 118, and 119. The former was first introduced by the Robins Conveying Belt Co.

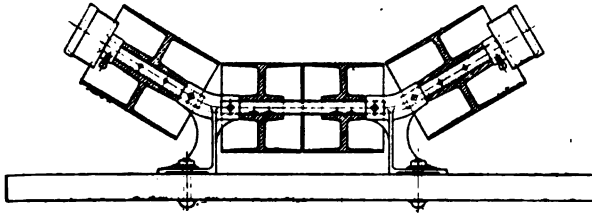


Fig. 116. Four-Roller Troughing Idler.

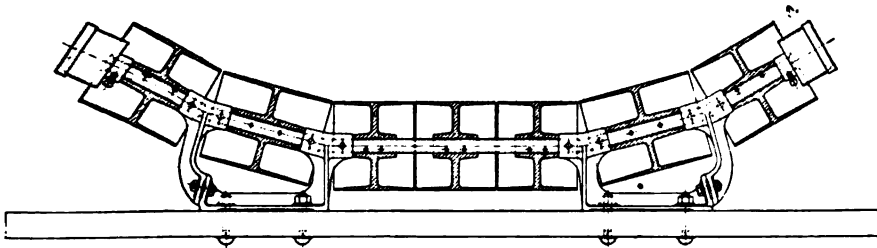


Fig. 117. Seven-Roller Troughing Idler.

about 1885, and is now almost universally used either as illustrated or with slight variations.

Theoretically, it cannot be considered correct to use idler pulleys of small diameter for narrow belts and larger ones for wide belts, as is generally the case. The belt speed should be taken into consideration, and fast-running belts should be fitted with larger, and slow-running ones with smaller, diameter rolls. Conveyors for grain and seed, which almost invariably run faster than those for minerals, generally have the

smallest diameter idlers, which is obviously wrong, as a glance at the following table illustrates.

With a belt speed of from 200 to 600 ft. per minute a 4-in. roller will make from 190 to 570 revs. per minute.

A	5-in. roller at the same speed will make 150 to 460 revs.			
A 6	"	"	"	125 ,, 375 "
A 7	"	"	"	110 ,, 330 "
A 8	"	"	"	100 ,, 300 "
A 9	"	"	"	85 ,, 255 "
A 10	"	"	"	75 ,, 225 "

Fig. 118. Five-Roller Troughing Idler of The Link Belt Co.

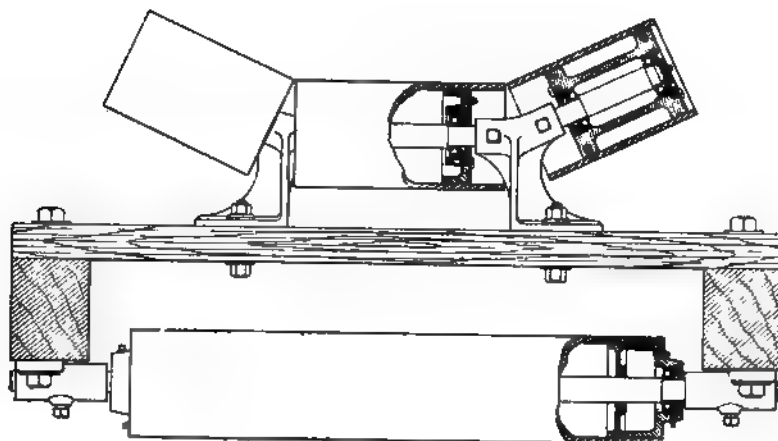


Fig. 119. The "Conweigh" Ball-bearing Troughing Idler.

From this table it will also be seen that the speed of the idler pulleys, except those of 4 in. and 5 in., at the high speed, is not too high to ensure satisfactory running, and, if properly lubricated, the weight of the belt alone should be sufficient to turn them easily. Should any of them become stuck it will be due to grit or insufficient lubrication.

The greater the number of rollers in each idler frame, and therefore the shorter each individual roller, the smaller the chance of damage by attrition to the belt in case of any one roller becoming fast.

The slope of the idler pulleys for troughing, as first introduced, stood at an angle of 40° to the horizontal, but was subsequently changed to anything between 30° and 25°, so as to avoid too sharp a bend in the belt. Later designs for wide belts use idlers with five and six rollers, to form a trough resembling a section of a circle. This gives sufficient

troughing to carry a large capacity, and ensures the centring of the load, thereby increasing the tendency for the belt to run straight.

Ball bearings for idlers have of late been introduced with great success. The advantages of this construction are obvious, as these idlers run so easily that it is quite impossible for them to get stuck, to the detriment of the belt or the expenditure of driving power. The makers of the idlers are The Conveying Weigher Co., of New York, and other firms.

Fig. 119 shows one of these sets of idlers, from which it will be seen that the whole of the bearing is enclosed in a dust-tight chamber in the interior of the rollers. The space is filled with sufficient lubricant to last from six to twelve months, according to whether the conveyor runs long or short hours.

The distance apart of the supports depends upon the weight of the material to be carried, and also upon the rigidity of the belt, a troughed belt being naturally more rigid than a flat one. The following table gives this information under average conditions and for troughed belts:—

Width of Belt.	Number of Plies in Belt.	Pitch of Idlers.			
		For Minerals.		For Grain and Seed.	
Inches.		Ft.	In.	Ft.	In.
10 to 16	3 to 4	4 6	to 5 0	5 6	to 6 0
18 „ 22	4 „ 5	4 0	„ 4 6	5 0	„ 5 6
24 „ 30	5 „ 6	3 6	„ 4 0	4 6	„ 5 0
32 „ 36	6 „ 7	3 0	„ 3 6	4 0	„ 4 6
38 „ 48	7 „ 8	2 6	„ 3 0	3 6	„ 4 0

Support of Return Strand.—The idlers supporting the return strand should be about twice as far apart, or say from 6 ft. to 12 ft.

Provided the return idlers are not too small in diameter, there is no detriment in spacing them a little further apart than stated, as the sagging of the return belt caused by this has a tendency to keep the working strand taut. The distance between these idlers has been known to be as much as 20 to 25 ft.

Lubrication of Idlers.—This is of great importance. Oil, of course, is the best lubricant; but as this is likely to spill on the belt, it is better to use a viscous lubricant, particularly when rubber belts are used, as the oil may injure the rubber. Grease-lubricated conveyors take slightly more power, but grease is a more suitable lubricant, as, when forced into the bearings in the usual way, it forms an effective dust protector for the journal.

Driving Terminals.—The driving mechanism of a belt conveyor is the simplest possible. It consists, in its original form, of a terminal or driving drum, or pulley, supported by a substantial spindle and pedestals, to which the driving power is applied. The terminal at the other end is similar, but is usually fitted with an adjustment for keeping the belt taut. These terminals are so simple and so well known that there is no call for going into further details, except to say that the drums should be stronger than ordinary pulleys, with a good rim and sufficient arms, particularly for wide conveyors, and they should be well rounded on the face. It is also advisable to secure the driving drum to the spindle with two keys 90° apart.

The following table gives the diameters and widths of terminal drums and guide and idler rollers, which are recommended for ordinary conditions.

If the pulley or drum is less in diameter than the dimensions given in the table,

the belt may not be sufficiently pliable to adhere closely to the pulley, and it is therefore questionable whether the full benefit of the pressure will be obtained.

DIMENSIONS OF TERMINALS, GUIDE PULLEYS AND SUPPORTING ROLLERS

Width of Belt.	Number of Plies in Belt.	Width of Pulleys and Rollers.	Diameter of Driving Terminal Pulleys.	Diameter of End Terminal Pulleys.	Diameter of Tightening and Throw-off Pulleys.	Diameter of Supporting Rollers.
Inches.		Inches.	Inches.	Inches.	Inches.	Inches.
10	3	12	15-18	12-15	12	4 ¹
12	3	14	15-18	12-15	12	4 ¹
14	3	16	15-18	12-15	12	5 ¹
16	4	18	21-24	15-18	15	5 ¹
18	4	20	21-24	15-18	15	6
20	4	22	21-24	15-18	15	6
22	5	24	24-30	18-22	18	6
24	5	28	24-30	18-22	18	8
26	5	30	24-30	21-24	18	8
28	5	34	24-30	21-24	18	8
30	6	36	30-36	24-30	21	8
32	6	38	30-36	24-30	21	8
34	6	40	30-36	24-30	21	8
36	6	44	30-36	24-30	21	8
38	7	46	36-42	30-36	24	10
40	7	48	36-42	30-36	24	10
42	7	50	36-42	30-36	24	10
44	8	52	42-48	36-42	27	10
46	8	54	42-48	36-42	27	10
48	8	56	42-48	36-42	27	10

Position of Drive.—At first it was a generally accepted rule that the tight side of the belt should, by preference, be used for conveying, as this is in a flatter condition than the other, particularly in cases of installations with flat belts. This practically meant that band conveyors should always be driven at the end at which they discharge their load, but it has been demonstrated within the last few years that conveyors work well on either the tight or slack side of the belt. This has increased the utility of the band conveyor considerably, as under these conditions it is quite immaterial from which terminal the conveyor is driven. Indeed, it might be driven at any point of its length between the terminals by employing multiple pulley drives to get sufficient contact between the driving drums and the belt. For this purpose, the belt passes over two or even more pulleys, which may be geared together, so as to revolve at the same periphery speed. Similar multiple pulleys have also been used for terminal drives in cases of extra long conveyors, and particularly in cases where the conveyor works in dusty places, or where in the cold season there is the possibility of belt and pulleys becoming slippery through frost or ice. To some extent the slip may be prevented by lagging the driving drum with india-rubber, and, according to Mr Haddock, an advantage of 7 per cent. is obtained in tractive power, so that a drum with rubber lagging will be useful not only for larger conveyors but also in cases where a slipping may be feared.

With the single pulley drive at either of the terminals, the belt must always be kept taut by some tightening device, as the grip of the driving drum on the belt depends upon this, whilst with a multiple pulley drive, the grip of this group of pulleys on the belt is so great that sufficient tractive force can be exercised without relying on the tension of the belt.

It has been urged that the belt will not stand being bent over pulleys in both directions when in tension, which is necessary with multiple drives, but with a first-class

¹ Fast-running conveyors, at say a belt speed exceeding 500 ft. per minute, should have 6-in. diam. rollers.

belt and drums of sufficient diameter no separation of the plies has so far been experienced. It will, however, be well to wait before giving a final decision on this subject, until installations with multiple pulley drives have been in use for a sufficient number of years, to see whether the life of a belt under these conditions is as long as with the ordinary terminal drive. At any rate, the ability to drive the conveyor from either terminal is of the greatest advantage. Frequently, two conveyors working in the same direction, one from the other, or from the same point in opposite directions, have been driven by one motor by the latter being situated at the junction of the two conveyors.

Driving Power.—The power required for driving belt conveyors is comparatively small; in fact, there is probably no conveyor system which is so economical on this point. The calculation is influenced by a great number of considerations, of which the number of plies and, consequently, the stiffness of the belt, the distance apart at which the supports are placed and the nature of the driving arrangement form the principal items, in addition to the load, length, and speed of the conveyor. The method of lubrication and the state of the atmosphere also influence the power consumed, and, as this latter as well as other conditions cannot be considered as permanent, it appears of little use to give formulas for elaborate calculations, as these would only be right for certain specific conditions. Opinions of experts also differ so much on this subject—which was shown during the discussion on the interesting papers of Messrs Titcomb, Baldwin, and Peck, read before the American Society of Mechanical Engineers—that it will probably be better, more to the point, and more useful to the user to give a table of horse powers calculated to give a sufficient margin of power for small contingencies. This table gives the power required for horizontal conveyors, which will be less for a downward and more for an upward incline.

HORSE POWER REQUIRED FOR BELT CONVEYORS 100 FT. LONG RUNNING AT A SPEED OF 100 FT. PER MINUTE, AND WITH A NORMAL LOAD OF THE DIFFERENT MATERIALS

Width of Belt in Inches.	For Handling Heavy Ore.		For Handling Coal.		For Handling Grain.	
	H.P. Consumed by Conveyor.	Additional H.P. Consumed by each Throw-off or Tripper.	H.P. Consumed by Conveyor.	Additional H.P. Consumed by each Throw-off or Tripper.	H.P. Consumed by Conveyor.	Additional H.P. Consumed by each Throw-off or Tripper.
10	.775	.25	.540	.25	.486	.25
12	.961	.50	.675	.50	.594	.25
14	1.147	.50	.840	.50	.702	.25
16	1.550	.50	1.080	.50	.810	.50
18	2.013	.75	1.316	.50	.952	.50
20	2.343	.75	1.512	.75	1.092	.75
22	2.838	1.00	1.792	.75	1.358	.75
24	3.636	1.25	2.250	.75	1.740	.75
26	4.320	1.50	2.670	1.00	1.925	.75
28	5.040	1.75	3.090	1.00	2.118	.75
30	5.760	2.00	3.540	1.25	2.310	1.00
32	6.747	2.25	4.096	1.50	2.707	1.00
34	7.254	2.50	4.416	1.75	2.950	1.00
36	8.151	3.00	4.768	1.75	3.200	1.25
38	9.348	3.25	5.635	2.00	3.815	1.50
40	10.168	3.50	6.355	2.00	4.130	1.75
42	10.806	3.75	6.405	2.25	4.725	1.75
44	11.644	4.00	6.790	2.50	5.320	2.00
46	12.505	4.25	7.175	2.75	5.915	2.25
48	13.366	4.50	7.560	3.00	6.895	2.50

It is a surprising fact that the power consumed by a band conveyor running empty may be as much as 35 per cent. to 75 per cent. of that consumed by the loaded conveyor, the percentage depending principally upon the load, length, and speed of the conveyor. It is obvious that the power consumed by the terminals does not increase *pro rata* with the length of the conveyor, and, therefore, the power thus consumed by the terminals of short conveyors may be the principal factor, but it becomes more and more insignificant as the conveyor is lengthened, whilst the power consumed in turning the idlers increases in direct proportion to the length and load of the conveyor, so that with short conveyors running idle the percentage of power consumed is smaller than with long conveyors.

The power required for band conveyors for grain is less than with any other grain conveyor. An 18-in. band travelling at 500 ft. per minute would convey 50 tons of grain per hour, and if 100 ft. long would consume 4.5 H.P.

Speed and Capacity.—The speed and capacity of belt conveyors depends entirely on the nature of the material to be handled and the width and shape of the belt. Materials like grain and seeds can be conveyed at the highest speed, as such materials will not be damaged by being delivered at a great velocity. The limit of speed is, therefore, only set by the resistance of the air to the passage of the material. If the grain or seeds are heavy, a speed of 500 to 700 ft. per minute is admissible, whilst if it contains much dust or chaff, or if the grain itself is light, like oats, the speed should not exceed 400 to 600 ft. per minute. Wheat and barley are generally conveyed at a speed of 500 to 550 ft., whilst maize beans, and other heavy seeds may be conveyed at the maximum speed of 600 ft. per minute.

The speed of belts for coal and minerals is altogether different. Here the speed is, in many cases, limited by the friability of the material and the consequent dust creation and deterioration of some materials through the impact at the delivery point. This refers particularly to coal and coke. There is an exception to this in cases in which the material does not deteriorate by breakage at the impact, but where the band has to run slower on account of fine material being mixed with the coarse, so that the same consideration comes into force as in the case of grain conveyors.

The best speed for large pieces is 150 to 250 ft. per minute, and the speed increases in proportion for material of a smaller size to a maximum speed of 500 to 600 ft. per minute.

The modern tendency, in extra large plant, is to run belts faster as their width increases, and even for large belts speeds of 500 ft. have been adopted. The following table gives the safe load for a belt, in cubic feet per minute, by multiplying the area of a uniform load with the speed in feet at which the belt travels:—

TABLE SHOWING SECTION OF LOAD IN SQUARE FEET WHICH CAN BE CARRIED WITH SAFETY IN A CONSTANT STREAM ON BELT CONVEYORS IF THE MATERIAL IS SMALL AND UNIFORM

Width of Belt in Inches.	Area or Cross Section of Load in Square Feet.		Width of Belt in Inches.	Area or Cross Section of Load in Square Feet.	
	For Flat Belts.	For Troughed Belts.		For Flat Belts.	For Troughed Belts.
10	0.015	0.05	30	0.203	0.47
12	0.026	0.06	32	0.253	0.53
14	0.042	0.08	34	0.29	0.60
16	0.055	0.11	36	0.33	0.66
18	0.07	0.15	38	0.367	0.75
20	0.085	0.18	40	0.41	0.83
22	0.114	0.23	42	0.455	0.91
24	0.139	0.28	44	0.506	1.00
26	0.164	0.33	46	0.557	1.08
28	0.19	0.40	48	0.608	1.12

BAND CONVEYORS

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CAPACITY OF BELT CONVEYORS FOR GRAIN AND SEEDS

Width of Belt in Inches.	Capacity in Tons per Hour at a Belt Speed of							
	400 ft. per Minute.		500 ft. per Minute.		600 ft. per Minute.		700 ft. per Minute.	
	Heavy Grain.	Light Grain.	Heavy Grain.	Light Grain.	Heavy Grain.	Light Grain.	Heavy Grain.	Light Grain.
10	8	6	10	8	12	10	14	11
12	15	10	18	12	22	14	26	17
14	22	14	27	18	33	22	38	25
16	30	19	37	24	44	29	51	34
18	37	26	46	32	55	38	65	45
20	47	32	58	40	70	48	82	56
22	60	40	75	50	90	60	105	70
24	73	48	92	60	110	72	128	84
26	87	58	108	72	130	86	152	101
28	100	67	125	84	150	101	175	118
30	116	78	145	98	174	118	203	137
32	133	90	167	112	200	134	233	157
34	153	102	192	123	230	154	268	179
36	173	116	217	145	260	174	303	203
38	193	130	242	162	290	194	338	227
40	217	144	271	180	325	216	379	252
42	240	160	300	200	360	240	420	280
44	266	178	333	220	400	264	466	308
46	293	192	367	240	440	288	513	336
48	320	212	400	265	480	318	560	371

CAPACITY OF BELT CONVEYORS WITH TROUGHING ROLLERS FOR MINERALS

Width of Belt in Inches.	Capacity in Cubic Feet per Hour at a Belt Speed of 100 ft. per Minute.	Maximum Ad- visable Speed in Feet per Minute.	Capacity in Cubic Feet per Hour at the Maximum Ad- visable Speed.	Largest Piece of Mineral not to Exceed	Speed of Belt in Feet per Minute for Conveying Coal Con- taining Pieces of the Size given in the Previous Column.	Capacity per Hour of Coal as per Previous Column.	
				Inches.		Cubic Feet.	Tons.
10	...	...	...	...	...	...	...
12	400	300	1,200	2	300	1,200	24
14	500	300	1,500	2	300	1,500	30
16	700	300	2,100	3	300	2,100	40
18	900	350	3,150	4	275	2,475	50
20	1,100	350	3,850	5	275	3,025	60
22	1,400	400	5,600	6	250	3,500	70
24	1,700	400	6,800	8	250	4,250	85
26	2,000	450	9,000	9	225	4,500	90
28	2,400	450	10,800	12	225	5,400	108
30	2,800	450	12,600	14	200	5,600	112
32	3,200	500	16,000	15	200	6,400	128
34	3,600	500	18,000	16	200	7,200	144
36	4,000	500	20,000	18	180	7,200	144
38	4,500	500	22,500	19	170	7,650	153
40	5,000	550	27,500	20	160	8,000	160
42	5,500	550	30,250	21	150	8,350	165
44	6,000	600	36,000	22	140	8,400	168
46	6,500	600	39,000	23	130	8,450	169
48	7,000	600	42,000	24	125	8,750	175

If the capacity is great, the width of the belt is determined by the load, but where the quantity is small and contains large pieces, the size of the largest piece determines the

width of the belt. In both cases the speed of the belt should not be faster than is necessary to carry the load, and it is often better to carry a bigger feed on a slower belt than a thinner feed on a faster belt. As a general rule it may be taken that with belt conveyors for

						The Speed of the Belt may be from
Minerals	-	-	-	-	-	400 to 700 ft. per minute.
Heavy grain and seeds	-	-	-	-	-	500 „ 700 „
Light grain	-	-	-	-	-	400 „ 600 „
Coal and coke	-	-	-	-	-	300 „ 500 „
Sacks and other big loads	-	-	-	-	-	150 „ 300 „
Passengers	-	-	-	-	-	100 „ 150 „
Sorting and picking	-	-	-	-	-	20 „ 60 „

The belts of conveyors generally keep clean from adherence of the materials they carry, but with some materials, such as clay, sugar, salt and other sticky substances, there is a tendency for the belt to convey small particles past the delivery point and deposit them where they may become a nuisance. In such cases, rotary brushes (manipulated from the belt) have been used successfully. Where materials containing acids or other corrosive fluids are conveyed by belt conveyors, the whole of the metal portion of the machinery, including the finished surfaces, should be painted with graphite or white lead paint.

Inclined Belt Conveyors.—Belt conveyors can be used not only in a horizontal position, but also with a slight upward or downward gradient. They can also be designed to embody all these three attributes in one and the same conveyor, provided the change from one to the other is accomplished by a gentle curve.

The maximum incline at which a belt will convey depends upon the angle of repose of the material to be handled and on its formation. The presence of a large proportion of spherical pieces, for instance, will not permit of a steep gradient, as they have a tendency to roll back.

It may also be noted, by observing a belt running up a comparatively steep incline, that there is a slight jar conveyed to the material wherever the belt negotiates a guide roll, which jar has a tendency to start some portion of the load to roll back. It is, therefore, recommended to place the supporting rollers closer together on all inclines, and particularly so where the maximum gradient is reached, thus keeping the belt more even and so doing away with the jar.

Materials like loose gravels, pebbles, or clinkers from revolving kilns, or all-round materials, which have a tendency to run backward, must not be conveyed on an upward gradient of more than 10° to 15°.

Conveyors for all other materials containing large pieces may have an upward gradient of 15° to 20°, without affecting the capacity, whilst material of a uniform and fine nature, such as sand, small coal and minerals, will negotiate an incline up to a maximum of 23°.

Ridgway's Belt Conveyor, for which some advantages are claimed, but which has never been used in this country to the writer's knowledge, was brought out by the Ridgway Belt Conveyor Co., of New York.

It consists of two bands running on top of each other instead of the ordinary single band. The idler rollers are cylindrical, similar to those shown in Fig. 114, and the band is therefore running flat; to this inner band are fixed at intervals concave wooden blocks, on which the upper band rests and forms a trough. With this arrangement the lower band is scarcely subjected to any wear and tear, as it never comes in contact with the material; only the upper band, therefore, requires renewing at a comparatively small cost, as the two bands are each only about half the thickness of the single bands generally in use.

Band Conveyors for Larger Individual Loads.—Cotton band conveyors, if the loaded strand is supported at frequent intervals, are also suitable for carrying sacks, pieces of cloth, and light packages, if free from nails, hoop iron, and sharp projections liable to cut the band. They are comparatively cheap in initial cost, easy to drive, and

Fig. 120. Sack Conveyor at the Mills of Messrs Leetham & Sons, York.

quiet in operation, the last feature being sometimes of special importance. Band conveyors, however, are not so suitable or so durable as chain and slat conveyors for heavy packing cases.

A sack conveyor installed at Messrs Leetham & Sons' Flour Mills, York, is illustrated in Fig. 120; it shows the conveyor loaded with sacks as they are taken from the warehouse

to the loading platform at the railway station. The sacks are delivered from the end of the conveyor at a sufficient speed to slide down a shoot and over an inclined table, practically into the man's hands ready for stacking in the wagon. There is another siding on the other side of the conveyor, and when the table is reversed the sacks slide over for the purpose of loading into another truck on that side. This loading process can go on without being interrupted, because whilst one truck is being loaded the full one can be removed and an empty one put in its place.

With this conveyor, twelve railway wagons can be loaded in one hour by two men.

The conveyor itself is a band of the ordinary construction, with the exception that it is built rather more substantially, and that the supporting rollers are 18 in. apart instead of 6 ft. The conveyor is altogether 350 ft. long, and the band is 26 in. wide.

This installation was the work of Messrs Spencer & Co., Ltd., of Melksham.

The "Sandvik" Flexible Steel Belt Conveyor.—This flexible steel belt, introduced by the Sandvik Iron Co., of Sandviken, Sweden, is undoubtedly an interesting addition to our mechanical appliances for handling material, as it has increased the application of the belt conveyor to hot and sticky substances, for which the textile belt is not suitable. The belt is similar to the steel measuring tapes known to every one, but of course of larger dimensions. It is produced from charcoal steel, cold rolled and hardened, of a thickness of $\frac{3}{4}$ to 1 mm., or approximately 19 to 20 B.W.G. It has a tensile strength of about 3 tons per inch width for bands 1 mm. thick. The widths so far manufactured are 10, 12, and 16 in., the latter being at present the limit, but several bands may be used to form one wider belt. The belts are rolled in maximum lengths of 300 ft., but can be joined to any desired length.

As regards the mechanical appliances necessary to carry these steel bands—their nature varying so much from that of textile belts—the supports must of necessity differ in several essential points, the most important diversion being that the terminals must not be less than 1 m. (40 in.) in diameter, and that the supporting idlers may be greatly reduced in number, or altogether dispensed with. The necessity of the large terminals is obvious, as the constant bending of a steel band over smaller pulleys would soon destroy it, and as the bands are very smooth, and remain in that condition, a large pulley surface is necessary to afford sufficient grip on the driving terminals. The reduction in the number of idlers, or the dispensing with them altogether, seems to be one of the greatest advantages attached to the use of this new system, as these parts of a band conveyor are always the greatest source of trouble, and the weak point in an otherwise excellent appliance. In cases where no idlers are used, the steel belt runs in the bottom of a wooden trough, and owing to the smooth surface of the steel and the constant polishing action taking place during the working of the conveyor, no perceptible resistance is offered to the progress of the band when the speed is once up; and such a support being continuous and unbroken—contrary to the support by idlers—they form excellent conveyors for a great many purposes, particularly for out-of-door work.

Another advantage not to be lost sight of is the facility with which the load can be removed at any point by a V-shaped or oblique plough, as those objections mentioned in connection with steel plate conveyors do not obtain with a smooth steel band. Last, but not least, the cost of the belt is said to be only one-third of that of a good textile rubber belt. As the life of the latter belt when exposed to the weather is considerably shortened, the Sandvik belt deserves special attention for exposed positions, as it is impervious to atmospheric influences. This is demonstrated by hundreds of installations running in Scandinavia under climatic conditions

which are more trying than in this country.

The general arrangement (with the few exceptions mentioned in the preceding remarks) of this steel band conveyor is similar to that of the ordinary belt conveyor. This may be seen from Figs. 121 and 122, the former being a single band 16 in. wide. The latter is a compound band composed of three widths; two bands run side by side leaving a space of about 4 in. between, and this space is covered by a third band running over the gap, and overlapping the two side bands by about 4 in. The centre band is put on with a little less tension than the other two, in order to secure an easy fitting of the bands, and as the greater part of the load is always carried in the centre, its weight will tend to keep the middle band tightly against the others. The band is joined transversely by a row of rivets, the holes being countersunk. About 16 ft. from the head end of the return strand is a kind of steering gear, which keeps the band in its proper position, but which, experience proves, can be done without.

The Terminal Drums.—

These, as already mentioned, should not be less than 40 in. in diameter, and, when conveying warm material, terminal drums up to 48 in. in diameter are used. They are always narrower than the band, contrary to the practice in textile belts, and this is to prevent any particles being caught between the bands and the drums. The terminals are generally ordinary cast-iron pulleys, slightly rounded, and it is very important that no hard

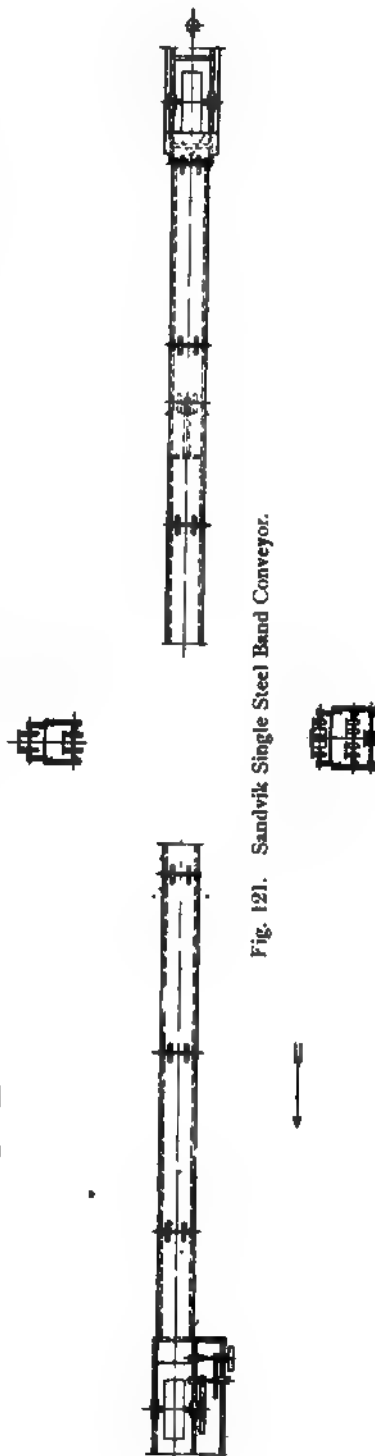


Fig. 121. Sandvik Single Steel Band Conveyor.

Fig. 122. Sandvik Compound Steel Band Conveyor.

substances should lodge between the terminals and the belt; some specially designed scrapers are arranged at the feeding terminal to prevent this.

The driving and tail terminals are shown to a small scale in Figs. 121 and 122. With a combined band there are three terminal drums, one for each of the bands, and to

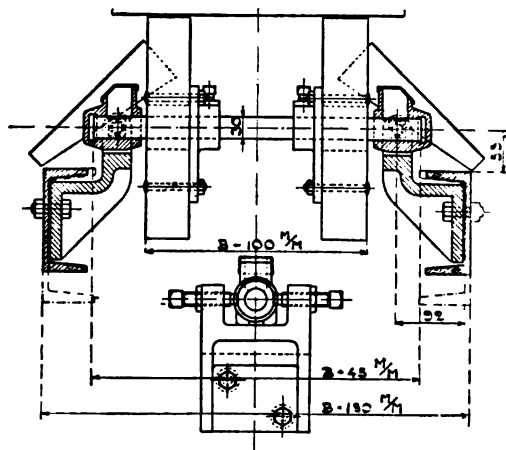


Fig. 123. Idlers for Sandvik Steel Band Conveyor.

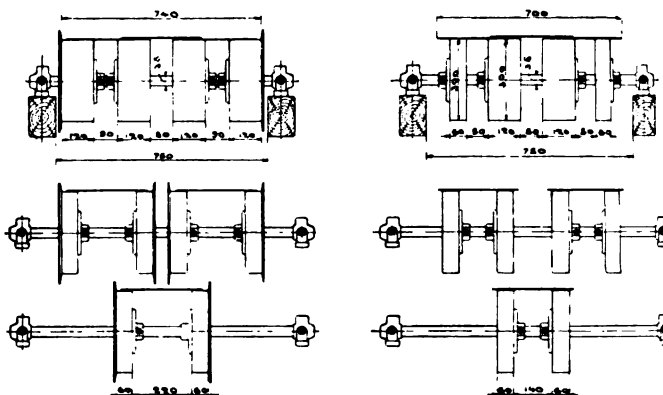


Fig. 124. Idlers for Sandvik Compound Steel Band Conveyor.

overcome the difficulty of any alteration in speed of the middle band, the drum for this is not keyed to the spindle, but runs freely on it. At the tail end one of the side sheaves

is keyed to the spindle, and the other two are loose. The tail or tightening terminal is fitted with a movable tension frame, which is held taut by a weight or by springs in order to compensate for any expansion which may be caused by the load or temperature. Short conveyors, carrying material of ordinary temperature, do not need tension frames.

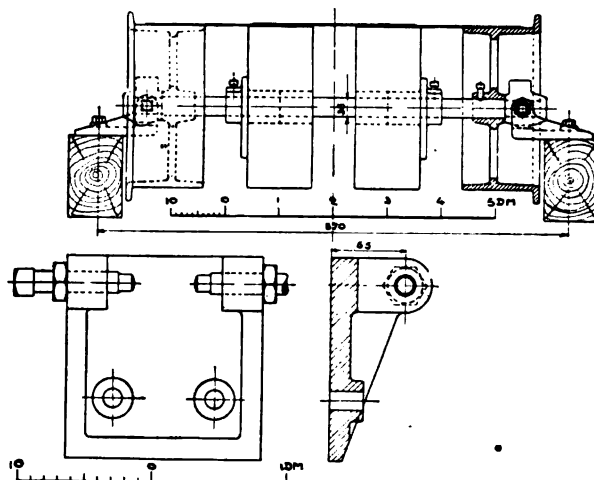
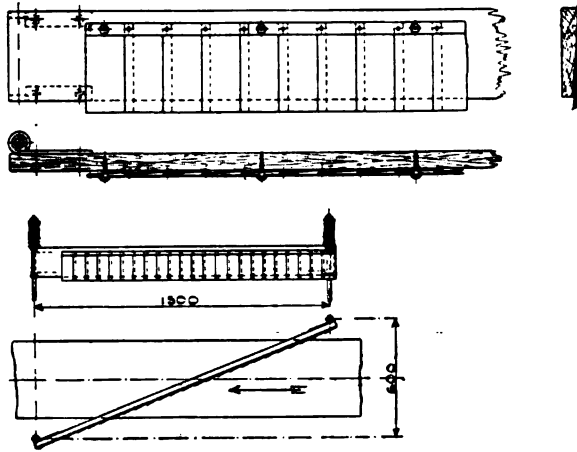


Fig. 125. Idlers for Sandvik Compound Steel Band Conveyor.

Idlers. — It has already been mentioned that these conveyors can work without idlers, but such an arrangement is only for a limited number of purposes. For more important installations idlers are used; they are 12 in. in diameter, and much narrower on the face than the

width of the band. Such idlers are shown in Figs. 123, 124, and 125 for single band and compound band conveyors. At intervals flanged idlers are used to prevent the belt from travelling to one side. The distance between the idlers varies from 6 to 14 ft., according to the weight of the material to be carried, and the return idlers may be as far as 35 ft. apart. On account of their rigidity steel bands cannot be troughed.

Intermediate delivery is effected by a plough either V-shaped or set obliquely across the band. The plough consists of a number of steel plates which overlap and form one continuous scraper, which is generally made portable and mounted on wheels. The illustrations, Figs. 126 to 129, which show different forms, explain themselves.



Figs. 126 and 127. Scraper for Intermediate Delivery from Steel Band Conveyors.

Inclination.—Inclines can be negotiated by these conveyors. The gradients, of course, depend, as with other conveyors, on the nature of the material, but in a general way an incline of 14° is permissible. The table on page 98 gives the capacity and horse power required from actual experience.

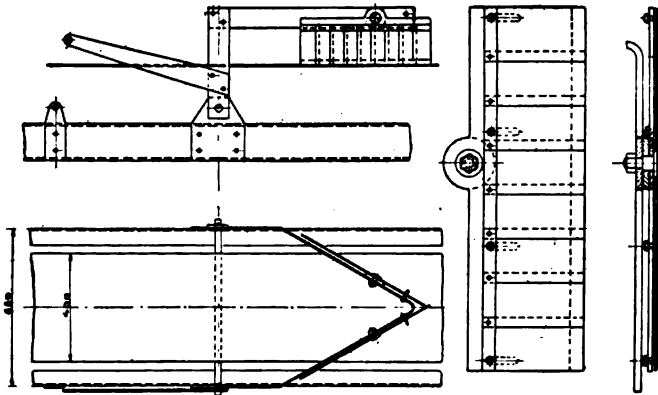


Fig. 128. Plough for Intermediate Delivery from Steel Band Conveyors.

Advantages and Disadvantages of Band Conveyors.—The great advantages of band conveyors are: the small driving power required to manipulate them, their noiseless and smooth working, their large capacity, non-injury to the material during the process of conveying, and their comparative security against breakdowns. It goes without saying that these advantages obtain only where first-class conveyors are installed, in the design of which all circumstances as to the nature of the material to be handled,

CAPACITY AND HORSE POWER CONSUMED BY THE SANDVIK BAND CONVEYOR FOR LENGTHS OF 100 M., OR SAY 328 FT., THE SPEED OF THE BELT BEING 300 FT. PER MINUTE.

Width of Belt.	Capacity in Cubic Feet per Hour.	Horse Power for Materials with a Specific Gravity of 1
Inches.		
10	180	1.2
12	550	1.3
16	950	1.6
28	3,000	2.5
40	7,500	3.4

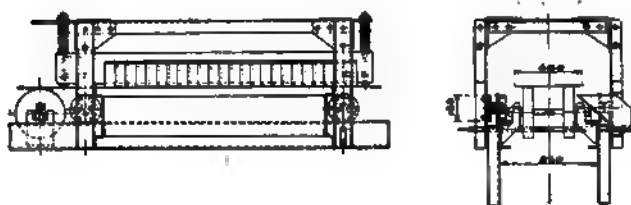
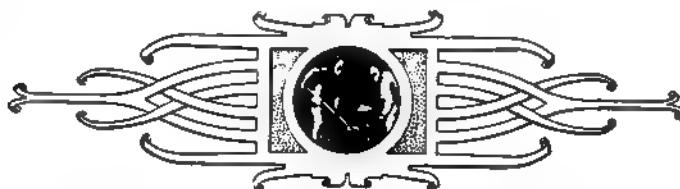


Fig. 129. Scraper or Plough for Intermediate Delivery from Steel Band Conveyors.

the speed of travel, the number and size of the supports, the construction of the terminals, and the system of lubrication have been carefully considered.

The disadvantages are: the feed cannot be withdrawn at intermediate points without the use of a more or less cumbersome throw-off carriage,¹ while in most cases the feed will have to be stopped if the delivery of the band is to be changed to a different point, and the great many small bearings which have to be oiled and kept in repair. As the rollers make 150 to 600 revs. per minute, these require considerable attention, unless ball-bearing idlers are used.

¹ This does not apply to the Steel Band Conveyor.



CONVEYORS

C.—APPLIANCES IN WHICH THE TROUGH CONTAINING THE MATERIAL MOVES BODILY WITH THE MATERIAL— *continued*

CHAPTER VIII

STEEL PLATE OR APRON CONVEYORS, SLAT CONVEYORS, PICKING BELTS, AND CONTINUOUS TROUGH CONVEYORS

STEEL PLATE OR APRON CONVEYORS

It is evident that there must be a point at which band conveyors of textile rubber and similar material can no longer be effectively used, and that point is reached when sharp and cutting substances or material has to be handled. Sometimes also a firmer base than that afforded by a band conveyor is desirable. In such cases it is usual to employ endless bands, so to speak, composed of a series of steel plates connected to suitable chains running beneath the plates. Such articulated conveyors are used in the same manner as band conveyors of rubber or cotton. Of course the steel plate conveyor is a more cumbrous appliance, travels at a much lower speed, and has a much more restricted field of usefulness than a rubber or textile band conveyor. The segments of steel plate conveyors are attached to chains either of malleable, cast, or wrought iron. The former are more frequently used because they can more readily be shaped, with suitable attachments, for any special work, and all kinds of carrying plates can easily be fitted to them.

Ordinary Ewart-type chains are not much used, because they wear rapidly, and are very liable to breakages when used for such heavy work; and though broken parts can no doubt be readily replaced, yet an accident to a conveyor must cause stoppage and delays. The form of conveyor more generally used is one in which the links are of malleable cast iron and are joined together by hardened steel pins, with renewable wearing parts such as made by the Ewart Chain Belt Co., Ltd. Where such conveyors are required for extra heavy and especially rough work, or where stoppages would be most detrimental, steel chains are usually employed, the links of which may either be short after the style of the Gall chain, or consist more frequently of long forged links of the same length as the width of the plates.

This type of conveyor generally delivers only at the driving terminal; but should intermediate delivery be required, a delivery scraper is fixed across the band at an angle of about 45°, to scrape the whole or part of the feed of the band into a shoot, or on to a stock heap. If the intermediate delivery is not confined to one or more fixed points, and if it be desirable that delivery should take place at any point in the length of the conveyor, a scraper is mounted obliquely on a suitable carriage which can be moved into any position for the purpose of intermediate delivery. Such an arrangement is in use at the coke yard of the Southall Gasworks.

The withdrawing of the feed from such a continuous steel plate has this drawback, that the frequent joints in the band produce a rasping action on the material during the

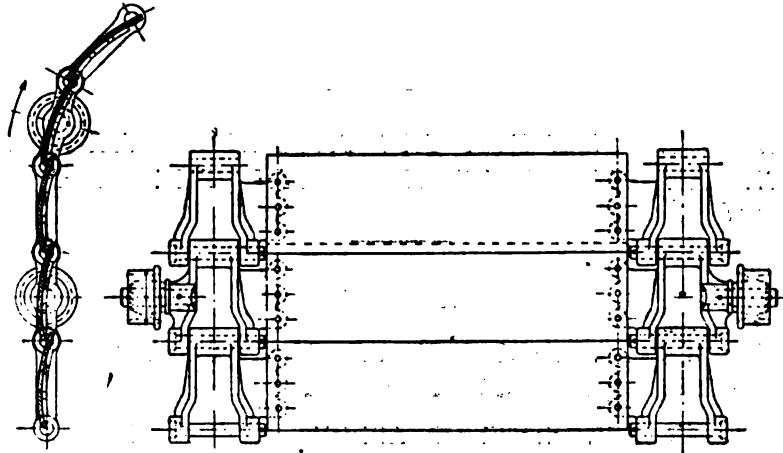


Fig. 130. Type of Steel Plate Conveyor.

process of scraping off, which is detrimental to such material as friable coal, and sometimes causes sufficient loss to make such an appliance impracticable.

Figs. 130 and 131 illustrate conveyors of this class. The convexity of the links in

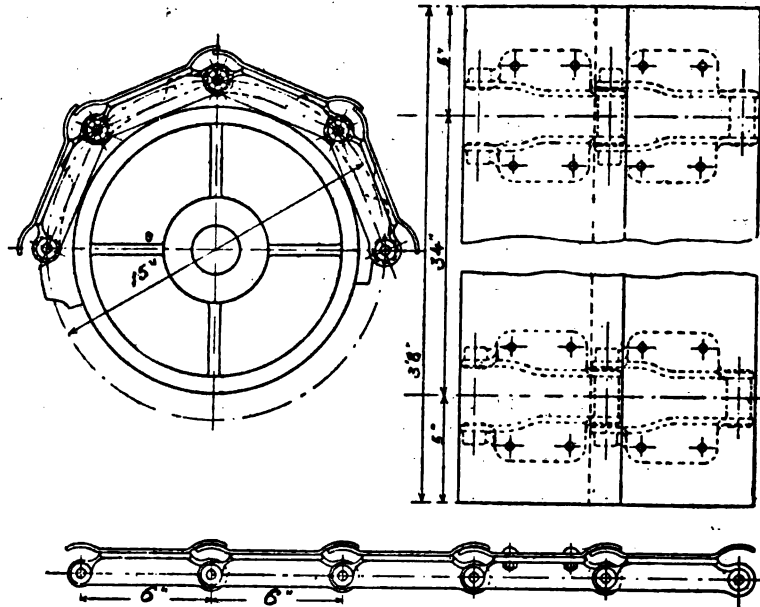


Fig. 131. Steel Plate Conveyor.

Fig. 130 gives them great strength, and is especially intended to facilitate the delivery of the material as the band reaches the terminal pulley.

In some of the best designed conveyors, each short segment of band is fitted with a narrow curved strip which is either part of the segment or is riveted in such a position

as to make a leakage between adjacent sections impossible, as the strip is just over the butt joint of the two sections. This strip is curved to allow the segments to bend freely when passing the terminals.

In Fig. 131 the surface of the plates is not convex but flat, with the exception of a slight curve at the joint just mentioned to allow of the plate ends interlocking.

Conveyors of this type are mostly used to handle large coal in collieries, and are often employed as picking tables for sorting coal and other materials whilst they are being conveyed. They also take the place of ordinary band conveyors, where the nature of the material to be conveyed would injure a rubber or textile band.

The belt is often supported at intervals by stationary rollers over which it travels. In more modern types (see Fig. 130) the rollers are attached to the links and travel with them, an arrangement which has the advantage of economising the driving power. The screeching of belts of the ordinary type, caused by the edges of the belt rubbing on the side angles, is avoided. Moreover, the points of the support being fixed relatively to the

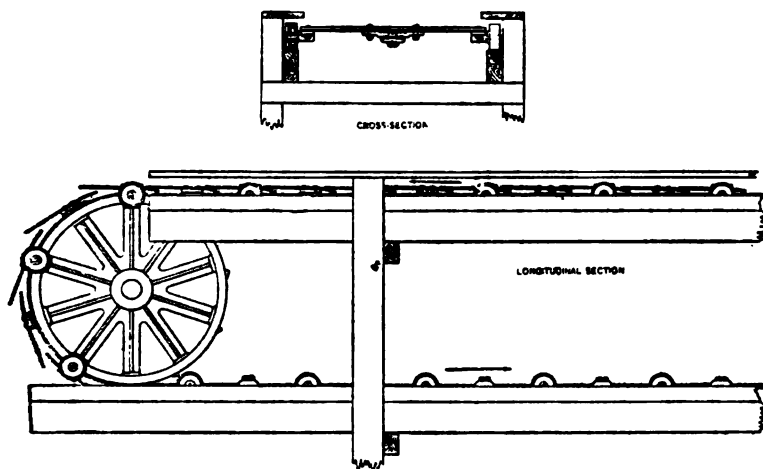


Fig. 132. Conveyor for Sorting Chips in Wood Pulp Mills.

belt, there is none of the irregular up-and-down motion sometimes met with on inferior bands, and the whole action is much smoother.

Fig. 132 represents a steel plate conveyor built by the Steel Cable Engineering Co., which is used for the purpose of sorting chips in wood pulp mills. These conveyors very much resemble colliery picking bands, and beyond the fact that the framework is of timber, they might be used for the same purpose.

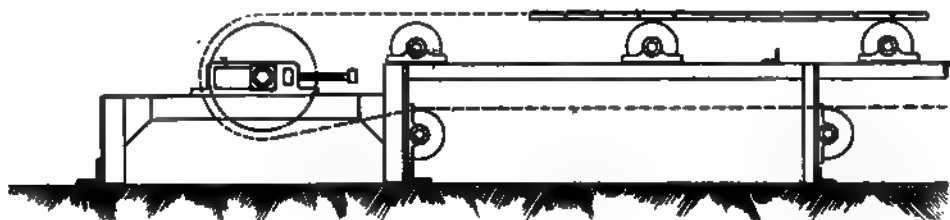
Every second section of the band has its own guide pulleys, which run on angle-iron tracks in the side of the framework, as seen in the cross section. The different plates overlap each other to make leakage impossible.

Unlike other conveyors of this type here mentioned, the one in question is driven by cables instead of by chains.

The tightening of these conveyors is effected in a similar manner to that of band conveyors, and the speed at which they run is 60 to 120 ft. per minute, according to the purpose for which they are employed.¹ The lower speed is adopted when the material is to be picked over.

¹ See Tightening Gears.

Metal plate conveyors are principally used for conveying coal, and have the great advantage of handling it so gently as to avoid breakage, provided of course that the delivery is at the terminal. There may be one drawback to the use of these conveyors beyond the keeping in repair of numerous small wearing parts, and that is that the



Figs. 133 and 134.

driving gear must always be at the delivery terminal of the conveyor to make the upper or working strand the tight side of the conveyor.

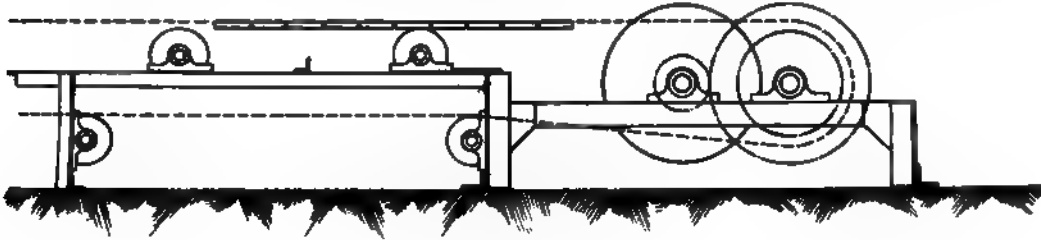
SLAT CONVEYORS

Chain and Wood Slat or Lattice Conveyors are most useful for conveying bales and packages in factories, also for sulphate of ammonia in bags. A typical example is given in Figs. 133, 134, and 135, showing elevation, plan, and cross section. Slat conveyors are used largely to carry substances in bags, also general merchandise packed in boxes and crates, or made up in pieces or bales. They can be made partly horizontal and partly inclined, and with either a single or double strand of chain, to which are bolted a series of narrow boards or slats (usually from 1 to $1\frac{1}{2}$ in. thick), forming a continuous travelling platform.

The terminals consist of one or two pairs of chain wheels; the bearings of those forming the tail end sliding in slotted frames, in order to permit of the extension of the chain being taken up by tension screws from time to time. Cast-iron supporting rollers or idlers about 9 in. diameter are provided at intervals of 3 ft. or more, the shafts running

in plain or bushed bearings fitted with stauffer grease lubricators. The outer rollers have a single guide flange; the inner rollers are plain. The bearings of the idlers are usually bolted to continuous channel steel beams.

A conveyor on similar lines has been erected by the Ewart Chain Belt Co., Ltd. It



Elevation and Plan of Wooden Slat Conveyor.

is 204 ft. long, the slats are 24 in. ; it travels at 50 ft. per minute, and handles 600 sacks of sulphate of ammonia of 2 cwt. each per hour. The chain used is No. 500 Gray Chain, 6 in. pitch.

In an alternative design of slat conveyor (Fig. 136) the slats are furnished with brackets and travelling wheels or rollers of small diameter, running on angle-iron tracks. This design has the advantage of avoiding the slight up-and-down movement of the packages in passing over fixed supporting rollers, due to the sag of the chain. Also the slats need not necessarily be close together, but can be spaced a foot or two apart in some cases. On the other hand, there is more difficulty in lubricating numerous travelling wheels than fixed bearings, and they are less secure and durable. Moreover, rollers revolving in contact with wood slats work more quietly than cast-iron wheels running on angle-iron tracks. A conveyor on these lines, built by the Ewart Chain Belt Co., Ltd., is worthy of note. It is 470 ft. centres, moving 2 cwt. bags of sugar at a large sugar refinery. It is driven by a 20 H.P. 3-phase motor



Fig. 135. Cross Section of Wooden Slat Conveyor.

at a speed of 70 ft. per minute. In this case the hard wood slats are 30 in. long and bolted to two strands of chain. The main lattice steel girders of the conveyor bridge are 7 ft. 6 in. deep, and are supported 20 ft. above the yard level by lattice steel towers and cross girders.

Double Service Chain and Slat Conveyors are also sometimes used. The special feature of this type of conveyor is that the return strand of chain and slats is not led back empty, but the two strands travel on the same plane in opposite directions, generally side by side, and both are utilised for carrying material. In this case the terminals are, of course, also placed horizontally. This conveyor is extremely useful for moving open crates, bottles, jars, tins and other goods needing careful handling. If the articles are not taken off they simply go round the circuit again and cannot be thrown off (see Fig. 269 on page 195).

PICKING BELTS OR TABLES WITH OR WITHOUT LOWERING ENDS

Picking belts or tables are used for removing stones and other impurities from coal and other minerals. They have also a place in cement works, where they are used for the purpose of picking the clinkers over.

Picking belts or tables in the form of ordinary band or steel plate conveyors have been mentioned in the foregoing pages, so that it is not necessary to describe their construction; but it may be useful to set forth the manner in which these appliances and their accessories are used.

In width, picking belts may vary from 3 to 5 ft.; 4 ft. 6 in. will be found a very suitable width if picking is to be done from both sides.

A great diversity of material is used for picking belts: but canvas, india-rubber, or woven wire is seldom used, at least not for the heavy work of dealing with South Wales and other large coal, where a hard surface is absolutely essential as well as substantial framework and carrying arrangements.

A very important matter is the discharge of the coal from the belt. If a fall of any depth is permitted, breakage results, and to some extent the result of the previous screening is vitiated. It is on this account that in some cases the picking belt has been provided with a jib extension, of which it is the special function to load the coal into wagons. If a separate loading device is used, a second fall seems to be unavoidable as the coal passes on and off the lowering device.

The belt shown in Fig. 130 is the nearest approach to a flexible steel band, and if it were a thoroughly practical appliance it would be an ideal picking belt. It consists of separate plates curved to form segments of the terminal drums carried upon double link chains and provided with rollers. The curvature given to the plates makes them very rigid transversely, but unfortunately the belt cannot be so made that the discharge shoot can be closely applied to the nearly cylindrical end. Hence, if placed high up to prevent any fall of the coal, the smaller particles will drop through the gap. The usual form of belt, composed of flat plates, attached to two or three link chains according to the width of the belt, has this drawback, that the delivery over the end can only be made by setting the receiving shoot well below the centre of the terminal drum, on account of the backward and forward motion on the end, according as the flats or the angles of the polygon drums are presented to the receiving shoot.

To overcome this difficulty, Howe's delivery shoot, Fig. 137, has been introduced, and has proved fairly efficient. The shoot A is so suspended as to have a tendency to lie close up to the belt terminus, and two upturned horns B one on either side are kept in contact with the conveyor plates, and serve to make the shoot follow and conform to the motion of the plates. In the illustration, the shoot A is shown as a short screen to

remove any fine coal which may have been produced on the conveyor. This improvement is occasionally met with. As mentioned elsewhere,¹ in some instances the picking band

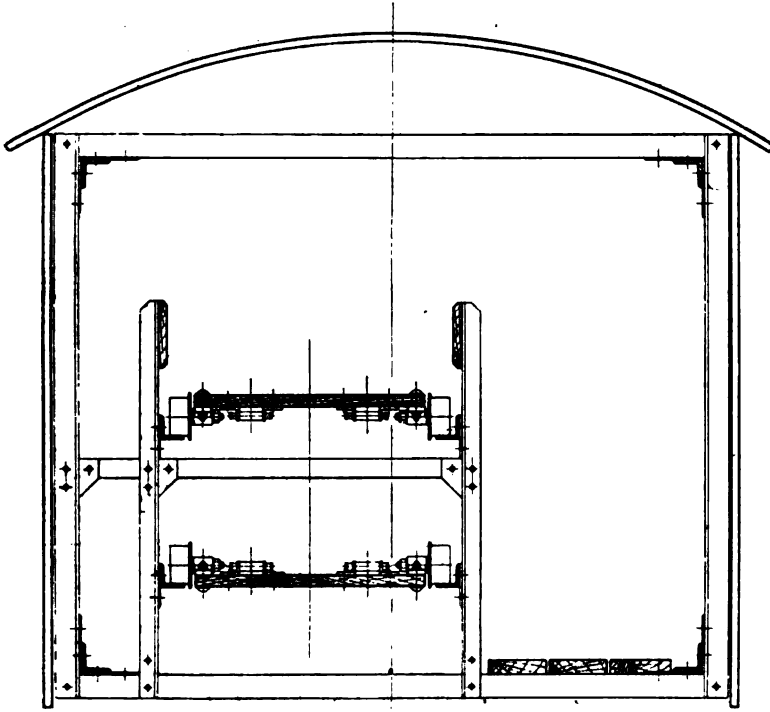


Fig. 136. Alternative Form of Slat Conveyor, having Rollers fixed to the Slats.

itself is extended to form a jib end which can be either raised or lowered into a suitable position, to lower the coal into wagons. This plan has two objections. In the first

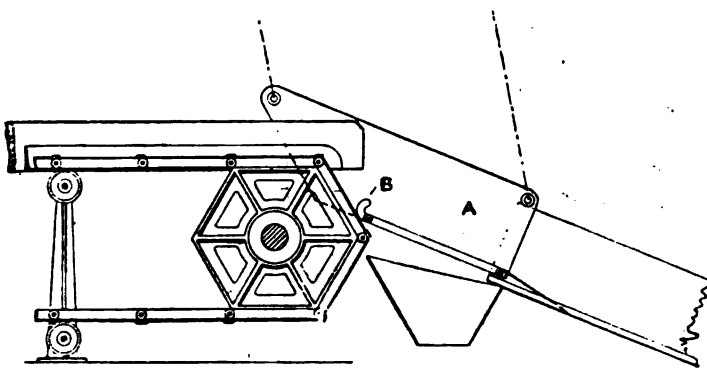


Fig. 137. Howe's Delivery Shoot.

place, the jib must be long enough to be at an angle at which the coal will not roll off it. As a consequence, the back portion of the wagon cannot be conveniently reached, and when starting to load, the coal has to fall at least the depth of the wagon, as the

¹ See Cornet Conveyor, page 110.

return belt on the under side has to clear the end of the wagon. The terminal drum of necessity occupies a considerable space, unless the belt is composed of very narrow plates and short links. In the second place, the return belt on the same side has to make a bend forming an obtuse angle at the top of the jib end, and if the plates have a normal amount of lap there is the danger of their being stripped off the links. This

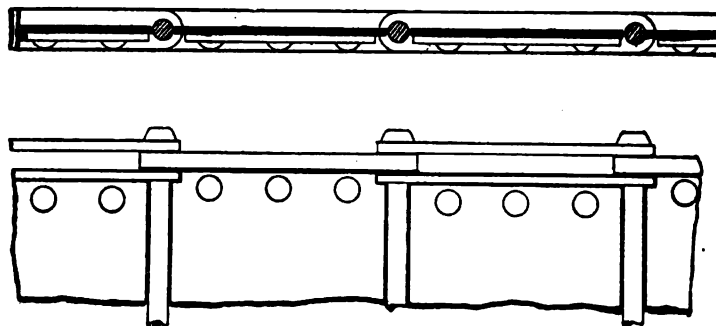


Fig. 138. Band which will Bend in either Direction.

latter difficulty may be met by making the links so that the centre of the pins coincide with the line of the plate (see Fig. 138).

In this case the belt bends equally well in either direction; but wear and tear in

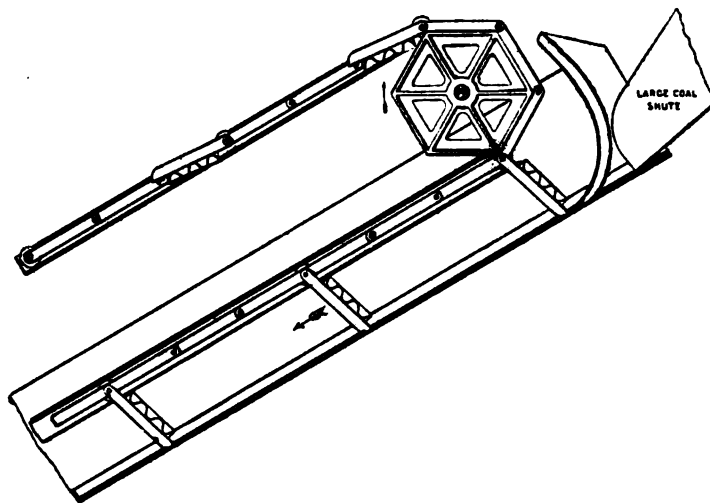


Fig. 139. Everett's Loading Device.

the joints will gradually cause gaps between the plates and the pins through which small coal may drop, this being an objection to an otherwise good design.

A much better plan is the provision of a separate lowering belt with shorter links, so that terminals of smaller diameter can be used, which may be four-sided only. This belt may be provided with a plain shoot in which the chains travel with the angle-bars between them at intervals, the angles serving to prevent the coal from running down the belt. Even under these conditions the hinder part of the wagon cannot be reached, and at the front end some drop of the coal is inevitable, for, if the cross-pieces are steeply

inclined, the larger fragments of coal will topple over them, while if they are made higher to prevent this, they require more room for clearing the wagon on the under side.

A vertical arrangement would appear to be the most suitable. Wrightson's coal shipper¹ and Soar's loader may be cited as suitable devices for loading work.

A further step towards the solution of the problem is seen in Fig. 139,² which represents an arrangement devised by Mr S. A. Everett for loading coal down a shoot. The return chain is here arranged above instead of below the shoot, and the obstructing plates, made for lightness' sake of corrugated metal, fold up on the return side, to economise space. By a kind of cam the flaps are made to open gently as they come

Fig. 140. Type of Continuous Trough Conveyor.

over the top terminal, and being deep, they permit the shoot being lowered to a very steep incline without allowing the coal to fall.

For the use of the Zimmer and Norton conveyors as picking and lowering devices, see pages 117 and 118.

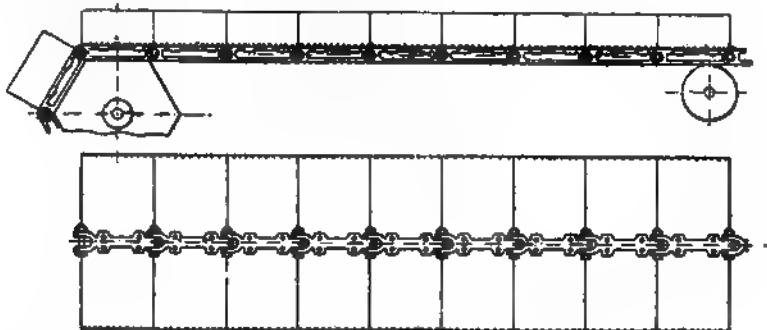


Fig. 141. Travelling Trough Conveyor with Single Chain.

CONTINUOUS OR ENDLESS TROUGH, TRAY, OR PAN CONVEYOR

This conveyor is practically the same as the metal plate conveyor, with this exception, that each segment has its sides turned up to form a trough, as is shown in Fig. 140. The endless trough travels over two terminal pulleys, one of which is adjustable to take up the wear in the joints of the chain.³ The sections of trough are also frequently fitted with small supporting rollers which run on angle-bars in the same manner as metal

¹ See description of Wrightson's Coal Shipper.

² From a description of Loading Devices in *The Iron and Coal Trades Review*, 6th April 1900.

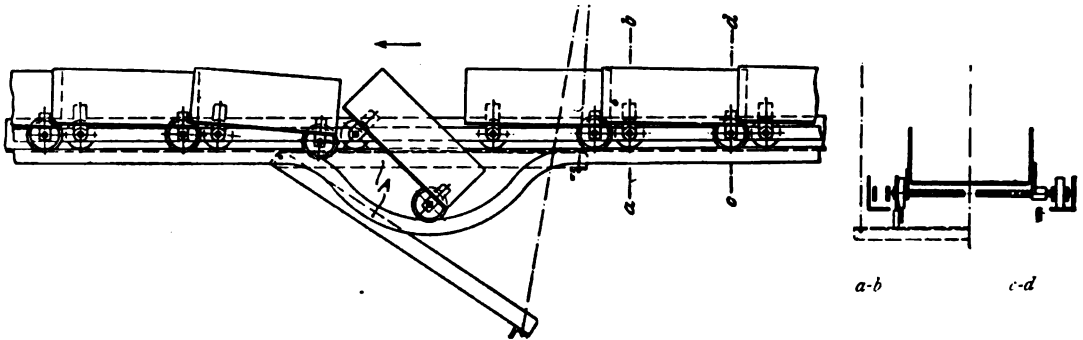
³ See Tightening Gears.

band and push-plate conveyors. These travelling trough conveyors have this advantage over push-plate conveyors, that they take less power and cause less breakage to the material. With this type, however, intermediate delivery is out of the question.

Fig. 141 shows a portion of such an endless trough conveyor with single strands and hexagonal terminals, which explains itself. This class of conveyor can also be used for small inclines without loss of capacity—inclines of 15° being quite permissible. In fact it may be used to convey up inclines up to 45° , but in such a case the segments of the conveyor are provided with projections or partitions which prevent the material from sliding back.

The speed of travel is 60 to 120 ft. per minute, or somewhat less than that of push-plate conveyors. There seems, however, to be no reason why they should not run at the same speed. The capacity can easily be found by multiplying the area of the trough by the speed of travel. Such conveyors have been made in lengths up to 500 ft., and for capacities of 100 tons per hour.

Intermediate Discharge.—It has been mentioned above that continuous trough



Figs. 142 and 143. Continuous Endless Trough Conveyor of the Link Belt Engineering Co.

conveyors are only applicable for end delivery, and in order to give a greater scope to this type of conveyor several important devices have been developed. They are all based on the same fundamental principle, namely, to have two chains, one on either side of the trough (instead of underneath), to which the segments of the trough are swivelled at one end, so that the loose end can be dropped for discharging, whilst during conveying this loose end is held up in some way or another.

The construction of the Link Belt Engineering Co. is shown in Figs. 142 and 143. The pans forming the trough overlap, and are fitted with two pairs of wheels each. The foremost pair has a spindle or axle which runs right through and forms at the same time the pivot of the links of the chain, and this pair of wheels run on an L track. The hind wheels have a shorter axle so that they are closer to the pan, and they run on a separate flat iron bar. The latter can be interrupted at the point or points of delivery, so that each pan in succession is dipped down and discharged, the wheels being guided down and up again on to the continuation of the flat iron track by a short auxiliary track.

This construction is somewhat simplified by the Jeffrey Manufacturing Co., who employ one L track only, so that the front axles remain in the normal position by the tension of the chain, whilst the back axles, which are free from the chain, allow that end of the pans to drop for discharging.

A conveyor, not unlike the preceding, and which is shown in Figs. 144 and 145, is

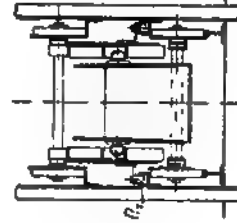
built by the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft. This differs in principle from the former in so far that the front end of the pan is raised for tipping, instead of the back end being lowered. This design has the advantage that a movable discharge carriage can be used, which facilitates the discharge at all points, whereas the conveyors previously described could only deliver at a number of predetermined points.

Each pan or segment of the trough is fitted with one pair of running rollers at the back end, the fore part resting on a flat iron bar riveted to the links of the chain. There are also two small rollers, one on each side of the fore part of the pan, and these engage with the rails of the tipping gear, and so empty each segment as it passes. The tipping gear is suspended on the rollers *r* and small channel rails.

Another example is the conveyor of the Bromberger Maschinenbauanstalt, Fig. 146. Here each segment of the trough has a projection like a handle on the under side. This comes in contact with a roller, and as the front end of the pan is pivoted to the chain, and therefore kept in position vertically, the back part of the pan is lifted, and this releases the previous segment, which rests on a ledge of the former, as seen in the illustration.

The Humboldt Company have a similar conveyor, though it consists of a series of bars instead of the sheet-iron pans. This is shown in Figs. 147 and 148. The bars of the grating of which each segment consists are hinged at *A* and held together by the bolt *s*. The links *x* of the chain form a raised edge to the trough (see cross section). The free ends of the bars are held up by the pendulum bracket *B* during conveyance. At the point of discharge is the tripper *C*, and as soon as the rollers *r*₁ come in contact with this, the pendulum bracket is bent out of its perpendicular position, and the loose end of the bar is released and falls down as shown in the illustration. The guide plate *D* afterwards raises the segment into its former horizontal position, where it catches again as before. The ends of the bars are cut obliquely, to drop behind the bracket *B'*, like the latch in a lock.

The Tipping Tray Conveyors of Babcock & Wilcox.—These are illustrated in the diagram, Fig. 149. Here the discharge is independent of the track, and each pair of rollers keeps to the normal rails, the tipping being effected by a lever *B*, attached to the forward end of each unit. The adjustable trip



Figs. 144 and 145. Continuous Trough Conveyor.

ping gear A is raised into position, and as the lever B engages with the tripper A, the buckets are discharged. At the driving end the units are guided round the terminal by an attachment C, and when leaving this the units of the tray hang down in a vertical direction, so as not to impede the fall of the material conveyed, in the event of no delivery shoot being found desirable. The chains, with their guide rollers used in these conveyors, are identical as used in the gravity bucket conveyor of the same firm.

TABLE GIVING DIMENSIONS, CAPACITY, AND SPEED OF THESE CONVEYORS

Width of Trough.	Depth of Trough.	Pitch of Chain.	Capacity in Tons of Coal per Hour.
ches.	Inches.	Inches.	
12	4	12	35
16	6	12	50
22	6	12	80
30	6	14	150
36	8	14	200
42	10	14	300

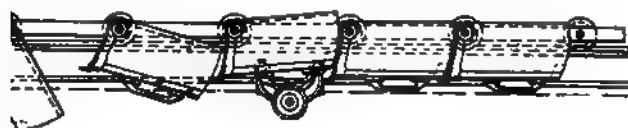


Fig. 146. Further Type of Continuous Trough Conveyor.

The normal speed of the conveyor is 60 ft. per minute, and the capacities given above are for these speeds, the maximum being 80 ft. per minute.

Smaller conveyors on the same principle, with capacities of from 6 to 20 tons per hour, are also made, but they have only single chains instead of double, the widths for these varying from 6 to 12 in. with a chain of a pitch of 6 in.

In cases where these conveyors are used for removing ashes and clinkers from boiler houses the whole of the working parts are covered on both sides at the loading point with sheet-iron guards, which are curved inwards at the top, covering the upper edge of the trough, so that no ashes can come in contact with the chain of the conveyor.

The Cornet Conveyor shown in Fig. 150 differs materially from the foregoing. It is used in connection with coal handling plants for loading and at the same time sifting coal. In this case the material to be conveyed is carried not on iron plates, but on a grating of round iron bars which are attached at both ends to the two driving chains. The idea is to carry the large coal on the grating in order to screen out through the apertures such small coal as may be mixed with it. The coal falls direct from the screen on to the band, receiving a

further screening as it passes along in a horizontal direction, and is then loaded directly into the railway trucks. To reduce as much as possible the fall of the coal, the delivery terminus of the band is made with a jib end, and can be raised or lowered by means of a small winch and chains according to the level of the coal in the truck. A counter-weight is used to balance the weight of the movable end.

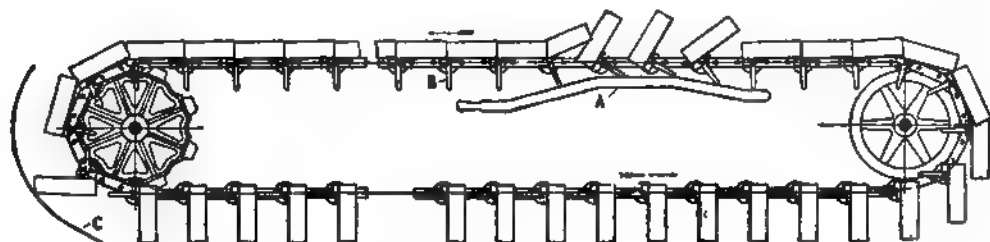


Fig. 149. Babcock & Wilcox's Tipping Tray Conveyor.

To every other link of the chain are fastened iron buckets, which serve to keep the coal from falling when on the inclined portion of the conveyor, and so prevent breakage of the material. These buckets also serve to collect the small coal which has fallen through the bars as the chain goes back empty, scraping it together after the manner

Fig. 150. Cornet Conveyor with Lowering Jib End.

of a push-plate conveyor. For this purpose the ends of every other scraper bucket are extended so that only half the buckets act as scrapers.

This apparatus is driven from a hexagonal terminal which is mounted, together with its countershaft, in adjustable brackets, for the purpose of tightening the band. The other terminal is only four-sided to save head room.

Each link of the conveyor is fitted with a pair of small rollers running in grooves.

CONVEYORS

D.—APPLIANCES IN WHICH THE MATERIAL IS CONVEYED BY THE ACTION OF A SEMI-STATIONARY RECIPRO- CATING TROUGH

CHAPTER IX

VIBRATING OR RECIPROCATING TROUGH CONVEYORS

THIS group embodies the latest developments of the conveyor. In principle it consists of troughs which receive the material to be conveyed at one end and deliver it at the other end by means of a succession of suitable backward and forward movements of the troughs. It may therefore be classed with the two previous types, *i.e.*, the band and the travelling trough conveyor, as in all three conveyors the material is, so to speak, conveyed in the trough without the use of a stirring or pushing agent, as is the case with worm, push-plate, and cable trough conveyors. It is obvious that every kind of material which deteriorates through rough treatment should be conveyed on appliances of the former types.

The credit of the introduction of this appliance in its original form is due to Eugen Kreiss, of Hamburg.

There are several varieties of the vibrating trough conveyor. In some, the trough makes a reciprocating motion by means of a crank and connecting rod, whilst the trough itself is supported on rollers (Thomson's patent) or portions of rollers (Marcus patent); others are actuated by a cam, or by cranks with some kind of quick return motion.

The support of the trough in its reciprocating motion has been effected by links and by spring legs in an oblique position, the latter form being more generally used for two reasons. Firstly, these spring legs are securely bolted at one end to the floor or other support, and at the other to the conveyor trough itself, and consequently require no lubrication. Secondly, the combined action of the reciprocating motion of the trough and of the rocking of the spring legs causes the material to travel faster in the trough with a given stroke of the crank than with any other support.

The Zimmer Conveyor.—This is built on the above principle. The diagram in Fig. 152 illustrates its action. The diagram is greatly exaggerated, as the movements are too minute to show on so small a scale. The lines A, B represent the bottom of the trough; C, C are two of the spring legs. The lines in full show these legs at the extreme backward position of the crank D, and the dotted lines also show A, B, C, C in the forward position of the crank. Let E be the object to be conveyed. At the moment the trough moves forward and upward, E is thrown also forward and approximately at right angles to the slanting legs C, C, and before E has time to complete its short parabolic course, the trough has been moved by the crank into its original position to receive it, when the same process repeats itself again and again, the progress of the object being indicated by E¹, E², E³. In reality the horizontal movement of

the trough is only about 1 in., and the vertical between the dotted and the full lines only $\frac{1}{8}$ in. If the trough is full the material moves, as it were, in a solid mass. There

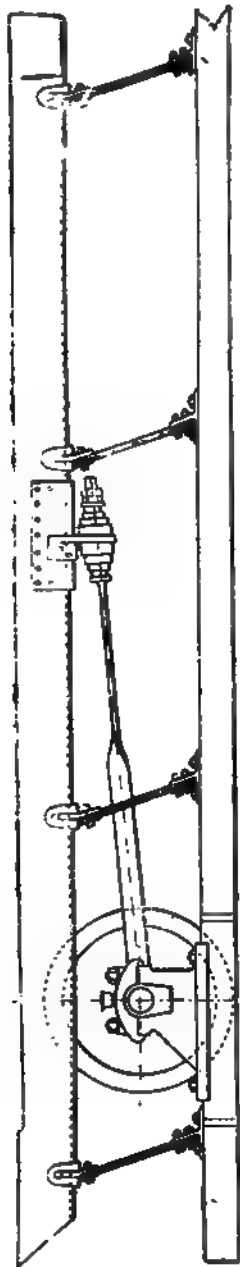


Fig. 151. Elevation of Zimmer Conveyor.

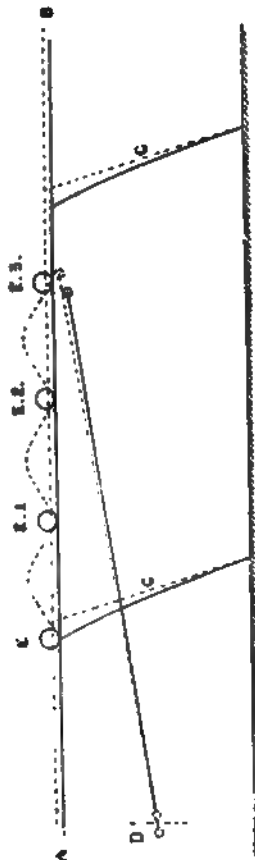


Fig. 152. Diagram showing Action of Zimmer Conveyor.

Fig. 153. Cross Section of Zimmer Conveyor.

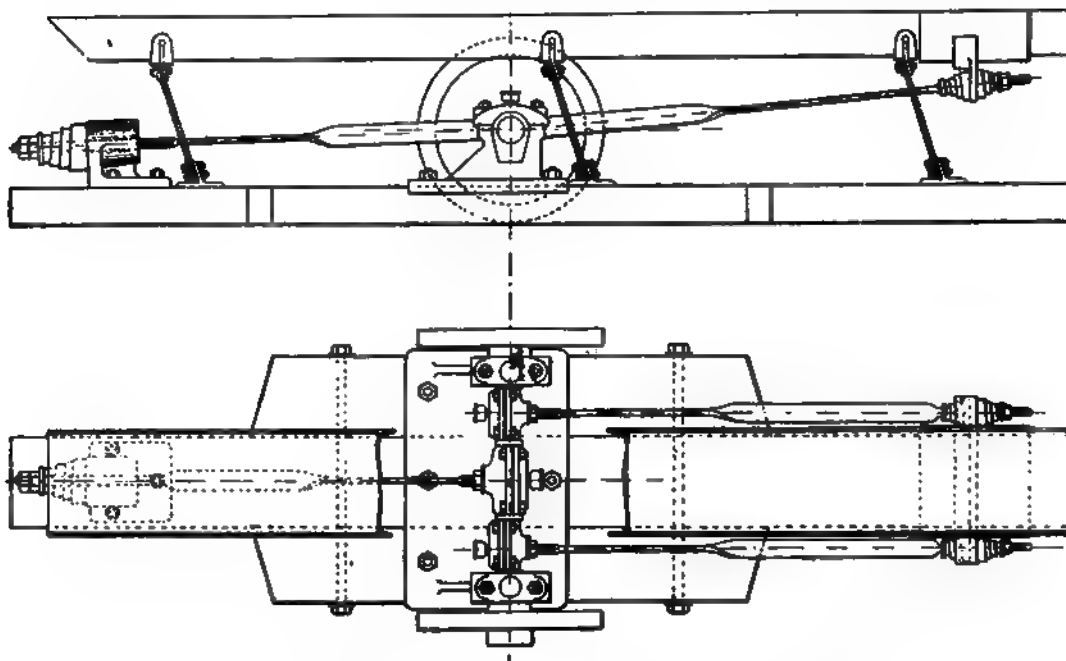
Fig. 154. Elevation of Balanced Zimmer Conveyor.

is neither friction between the particles of material nor between the trough and the product, as it is a hopping and not a sliding motion which propels the material.

Figs. 151 and 153 show one of these conveyors in elevation and in cross section. It is of the original type with a few improvements. Such a conveyor would be suitable

for lengths of 50 ft., and for widths up to 24 in. It has been shown that the original conveyor could only be used in comparatively narrow limits; but this appliance has now been improved, and is well known, especially in colliery districts, as the "Zimmer Conveyor." It is used in lengths up to 500 ft. for narrow widths, and in widths up to 6 ft. 6 in. for short lengths. The essential improvement which rendered it possible for this conveyor to be made in such proportions was the introduction of the balancing device, by means of which the conveyor is made in two halves, one being about 2 in. higher than the other, so that one half delivers into the other half. The two sections are manipulated by triple and multiple cranks which stand at an angle of about 180° to each other. One half of the conveyor moves forward whilst the other moves backward, and at the same time the material is moved from end to end and in the same direction, as all the spring legs are of the same inclination. A portion of such a balanced conveyor is shown in Figs. 154 and 155.

Ordinary balanced conveyors are necessarily driven at or near the centre of their length. In cases where this is not convenient, they may be driven at one end, as shown



Figs. 156 and 157. Zimmer Conveyor Balanced by Terminal Volute Spring.

in Figs. 156 and 157. In this type the balancing of the conveyor is effected by means of a powerful volute spring, which is compressed and released by one of the cranks and connecting rods, instead of being coupled to one half of the conveyor. This acts as an accumulator, receiving and storing the surplus energy of the conveyor at its backward

VIBRATING OR RECIPROCATING TROUGH CONVEYORS 115

movement, and giving it up again as soon as the crank has passed the dead centre, where it is utilised to pull the conveyor back against the springs.

The Zimmer conveyor can be used to work partly in one direction and partly in another direction, by reversing the incline of the spring legs, and by joining the segments of the troughs at the junction by a flexible coupling.

The load can be fed into or withdrawn from these conveyors at any number of points without cessation of work. The material travels at the rate of 40 to 70 ft. per minute when the conveyor is driven at 300 to 370 revs. per minute, but the best speed is 300 to 350 revs.

The coupling between the trough and the connecting rod is not rigid, but two strong volute springs are placed on either side of the attachment. This is for the purpose of allowing the trough itself to exceed the stroke of the crank by a fraction of an inch on either side, and as the radius of the crank is in most cases less than $\frac{1}{2}$ in., the total travel of the trough with each revolution of the crank is but little more than 1 in.

The work of conveyors on this principle is not limited to a horizontal direction, as they can equally well be used for conveying material up and down slight inclines. They may be worked in a standing or hanging position, the conveyor in the latter case being suspended by its spring legs from the structure above.

The success of this conveyor is largely due to its simplicity and to the small driving power required, especially when it is fitted with the balanced drive, as in such a case half the spring legs are always in tension while the other half are relaxed, so that the power which has been stored in half the legs is utilised for tightening the other half immediately the crank has passed its dead centre.

The following tables give the capacity of this conveyor in tons of coal and coke per hour for different sized troughs :—

CAPACITY OF ZIMMER CONVEYOR FOR COAL

	Width of Trough in Inches.								
	12	14	16	20	24	36	48	60	72
Trough 4 in. deep -	Tons. 6-7	Tons. 7-8	Tons. 8-9	Tons. 10-12	Tons. 13-15	Tons. ...	Tons. ...	Tons. ...	Tons. ...
„ 6 „ -	9-10	12-13	13-15	16-18	18-20	30-32	35-40	45-50	50-60
„ 8 „ -	...	...	...	...	25-30	35-40	50-60	60-70	70-80

CAPACITY OF ZIMMER CONVEYOR FOR COKE

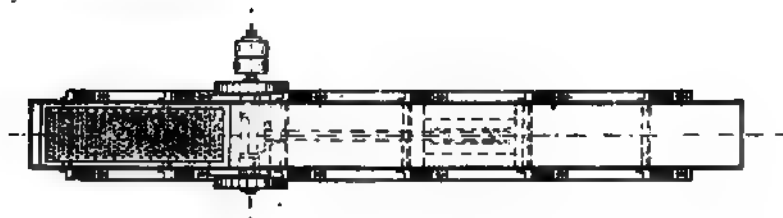
	Width of Trough in Inches.								
	12	14	16	20	24	36	48	60	72
Trough 4 in. deep -	Tons. 3½-4	Tons. 4-5	Tons. 5-6	Tons. 6-8	Tons. 8-10	Tons. 10-13	Tons. 16-19	Tons. 19-22	Tons. 22-26
„ 6 „ -	...	...	...	...	12-14	16-19	24-28	28-33	33-39
„ 8 „ -	...	...	...	...	16-19	22-26	33-39	39-46	46-53

The capacities given in the tables are for conveyors in a horizontal position. An incline of only 5 per cent. downwards will increase the capacity with some materials up to 10 per cent., while an incline upwards will reduce the capacity accordingly.

The driving power required may be judged from the following example. A Zimmer conveyor 100 ft. long, conveying a load of 50 tons per hour, will require 8.75 H.P.

The advantages of this conveyor are that it will convey any kind of material in large or small pieces, and cause next to no breakage to even the most friable material on account of its gentle action. By the use of ordinary slides in the bottom of the trough, the material can be withdrawn at any number of points. There are but few parts, and fewer still to get out of order, whilst a special feature is the absence of a multiplicity of bearings and travelling gear.

This conveyor is used for a variety of purposes, a few of which are herewith illustrated and described.



Figs. 158 and 159. Zimmer Conveyor as used for Draining Purposes in connection with Coal-Washing Plant.

Figs. 158 and 159 show the conveyor for draining purposes in connection with a coal-washing plant. The head end of the conveyor being fitted with a perforated plate, allows the water to at once escape, whilst the coal is conveyed to the further end. The conveyor has a slight upward incline; thus should any water remain with the coal, it will tend to run back towards the feed end where it can escape through the perforations.

The conveyor can also be used as a picking table, as the oscillating motion of the trough does not inconvenience the pickers after the first few minutes, and it has this advantage, that the coal is always uniformly spread out over the whole surface. Hence picking is much easier work on this kind of conveyor than on the ordinary steel plate table, where the coal remains in heaps just as it has been deposited on the band, and has therefore to be spread for examination by the pickers.

Fig. 160 shows two Zimmer conveyors at work, which are used for picking purposes,

at the Amelia Pit of the Cramlington Coal Co., Ltd., while Fig. 161 shows a Zimmer patent balanced screen to a larger scale.

This conveyor is also extensively used in collieries, etc., not only for conveying, but also for classifying or sorting coal and other minerals into different sizes. When used as a screen, the machine is fitted with an interchangeable sieve which divides the trough into an upper and lower deck or compartment; the fine material which has been sifted out by this perforated plate is conveyed on the bottom of the conveyor until an outlet is reached. The sifting action is so sharp, that a perforated plate of 6 or 8 ft. in length is sufficient in most cases to effect the separation. The sieves for

Fig. 160. Zimmer Conveyor as used for Picking Purposes.

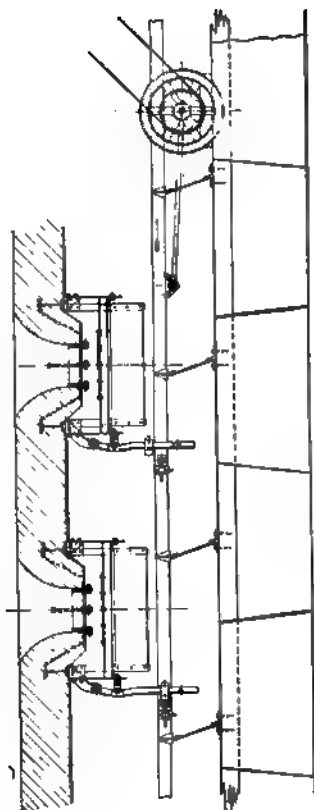
different sized coal required can therefore be made of such lengths as to coincide with the row of sidings on which the trucks to be loaded can stand.

The Weiss Feeding Appliance.—The feeding device illustrated in Figs. 162 and 163 is the invention of Mr Weiss, manager of the gasworks at Zürich, and has been designed for the purpose of automatically and uniformly feeding this type of conveyor with coal from silos or stock heaps.

The illustration represents the apparatus in elevation and cross section. The conveyor is fixed in a tunnel, with the feeding appliance over it, in connection with the hoppers bottom of the coal store.

The feeding device consists principally of a table above which the coal enters. This table is set into an oscillating movement, and thus allows the coal to drop from its sides into a small hoppers trough, from which it finds its way on to the conveyor. The oscillating motion is imparted to the table by a lever connected to the conveyor. This

Fig. 161. Zimmer Patent Balanced Screening Conveyor.



Figs. 162 and 163. Weiss Feeding Appliance in connection with Reciprocating Conveyors.

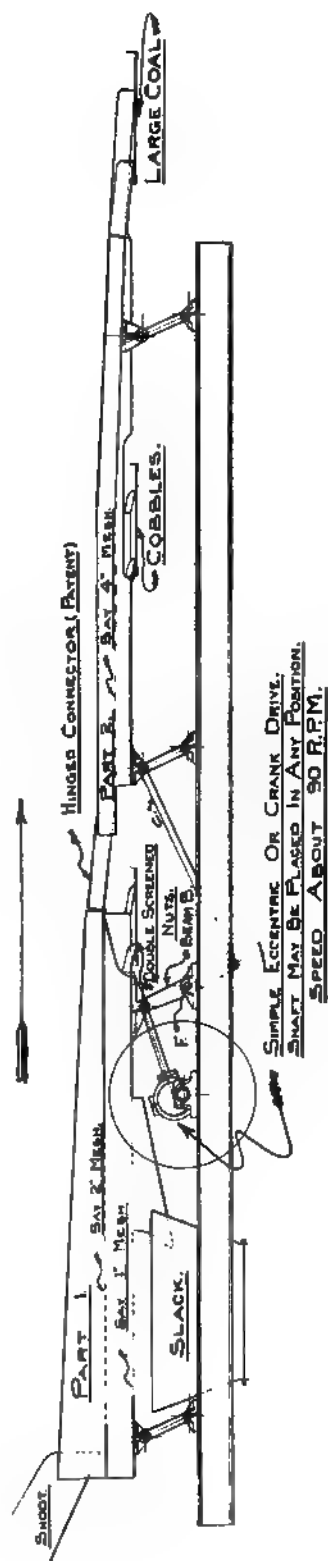


Fig. 164. Norton's Patent Reciprocating Conveyor.

lever can be thrown in and out of gear, and it is obvious that when thrown out and the table at rest, the flow of coal will cease.

The Norton Conveyor.—This is another type of reciprocating conveyor, and unlike that previously described, the trough is supported on inclined links, the stroke is much larger, and the speed of running much less. The conveyor consists of the usual wrought-iron trough, which in this case receives its reciprocating motion from an eccentric, and in order to balance the conveyor, the trough is made in two equal portions, which reciprocate in opposite directions. The motion is given by rocking levers (see Fig. 164), which shows the principle in diagrammatic form, which will be understood from the previous remarks. The diagram shows the development of this conveyor for screening purposes to classify the coal as well as to convey it. The number of inclined supports are comparatively few, as compared with the previously described conveyor. The speed of the eccentric is about 90 revs. per minute, and the stroke imparted is from 5 to 6 in., which is said to produce a forward motion of the material in the trough at the rate of 40 ft. per minute. From these particulars the capacities of the various sized troughs can be ascertained.

One of the most important features of this conveyor in connection with its use in collieries is the reciprocating loading extension, which is worthy of more than a passing remark. The loading or lowering device is so coupled to the conveyor or screen proper, that the stroke is automatically adjusted, and thus made suitable to every incline of the shoot, that is to say, at the steepest downward gradient, when the loader reaches to the bottom of the coal truck, and when the coal would run down by gravity at the ordinary stroke, this motion is only about 1 in., whilst when the incline is lessened as the truck is gradually filled from the shoot, the stroke increases automatically until when level it is as long as that of the screen. This diversion in the length of the stroke is produced by two levers, one on each side of the lowering jib, one end of each of these levers being hinged to a sliding block fixed to the floor, whilst the other end is guided by two rocking levers with slots (the rocking levers are manipulated by the screen). These two levers are connected on both sides at about the centre of their length to the lowering shoot, in such a way that when this is steep the ends of the levers are in the lowest position of the slots in the rocking levers, where the stroke is short, and as the shoot is raised the two lever ends ascend in the slots of the rockers to where the stroke is longer. The lowering shoot is 20 ft. long, and of course as wide as the conveyor screen from which it is fed and driven. The free or delivery end of this loading device is supported and adjusted by a small winch, a wire rope, and balance weight.

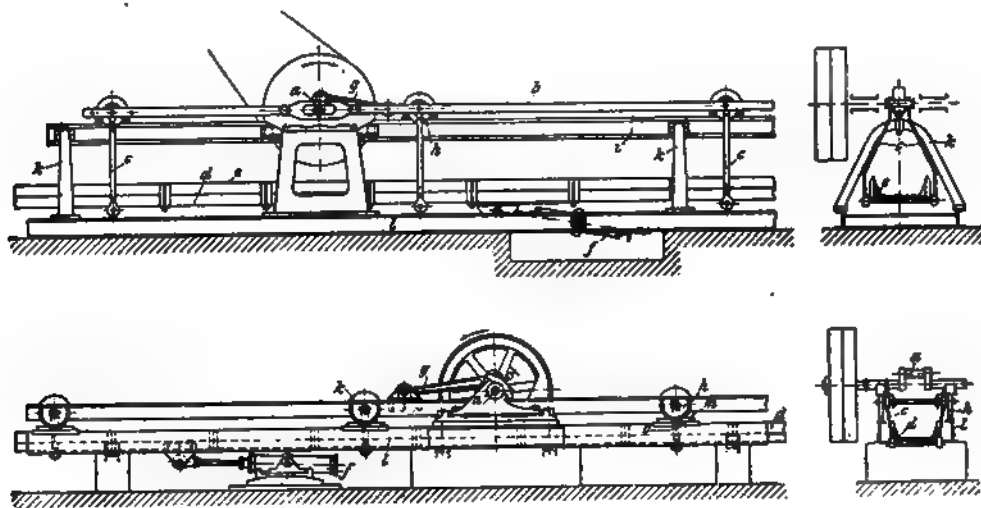
The Torpedo Conveyor.—A reciprocating conveyor has recently been introduced under this name, which presents some new features and an entirely different principle to the foregoing. Figs. 165 and 166 show the two types of this conveyor in elevation and cross section. The former is the standard type, whilst the latter is used when the available head room is limited.

A conveyor according to Fig. 165 consists of the following component parts: the trough *de* suspended on rockers *c*; the crank drive *ag* which conveys an oscillating motion to the frame *b*, which is supported by rollers *h*, rail *i*, and brackets *k*; and lastly of the dashpot *f* with its connection to the trough. Fig. 167 is a perspective view of the same.

The conveyor in the lower illustration (Fig. 166) differs from the one previously described in so far that the upper rail is dispensed with, so that the rollers *h* revolve on the channel *l*, or rather on chilled iron rollers *m*, the rockers *c* being in this case much shorter. The troughs are of angles and sheet steel plates similar to other reciprocating conveyors.

When the conveyor is at work the carriage has a reciprocating motion of 8 in., due

to the crank, and this motion is imparted by the links *c* to the trough. Such a swinging or pendulum-like motion being equal in either direction would give no forward movement



Figs. 165 and 166. Torpedo Conveyors in Elevation and Cross Section.

to any material deposited in the trough, and this motion does not come into being till the motion in one of the directions is arrested prematurely by the dashpot *f* and its connection. The action is then as follows: the material in the trough swings with the trough and has therefore the same velocity, but before the motion has reached its full extent the progress of the trough is gently checked when the material slides on by its momentum, and is thus conveyed by the repetition of this action. The normal speed of the crank is 52 revs. per minute, and the stroke 8 in.

Fig. 167. Perspective View of Torpedo Conveyor.

Reciprocating conveyors do not deserve this name until a certain minimum speed has been reached. In the case of the torpedo conveyor this appears to be at a little over 40 revolutions. At 52 revolutions the best results are obtained. According to Baron Hanffstengel, if the links *c* are 14 in. long, the stroke 8, and the speed 51 revolutions, the actual stroke of the trough is 9 in., and the average speed of conveying 62 ft. per minute. He also found that the material followed the backward stroke of the trough for 3 to 4 in.

The Marcus Conveyor.—The principle of this conveyor is that a horizontal trough is made to move backwards and forwards over the top of live supporting wheels; this works at from 60 to 80 strokes per minute. The driving gear (see Fig. 168) is so constructed that cranks on two shafts—which are placed out of line horizontally and vertically—are coupled together by a propulsion link. This peculiar form of mechanism

gives a variable speed to the backwards and forwards horizontal travel of the trough. Moving slowly at the commencement of the forward stroke, the trough is given uniform acceleration up to about three-quarters of the stroke, then slows down during the last

Fig. 169. Driving Gear for the "Marcus" Patent Conveyor.

Fig. 160. Marcus Conveyor at the Gealing Colliery.

quarter, reverses, and the return stroke is inversely the same as the forward, or instead of uniform acceleration in velocity there is uniform retardation. The material is carried with the trough in its forward stroke, and as the trough increases in velocity, sufficient impetus is imparted to the material to overcome its frictional contact with the trough in its backward stroke. Hence the material in the trough travels a distance nearly equal to the stroke at each revolution of the propulsion gear. These gears are made in four sizes:—

No. 1 gear, 8-inch stroke	-	-	78	revs. per minute.
" 2 " 10 "	-	-	72	" "
" 3 " 12 "	-	-	64	" "
" 4 " 12 "	-	-	64	" "

The advantages claimed for this system of conveying and screening are as follows: as the conveyor can be horizontal or inclined in the opposite direction to the ordinary screen, it will be seen that the height of the structures can be materially reduced. The operation of picking the coal can be carried on while it is being screened, and as at each stroke of the trough the coal changes its position, there is little chance of shale or refuse being hidden under good coal and so escaping the eyes of the pickers. When once pickers have become accustomed to the operation, they prefer to work on reciprocating conveyors to picking on ordinary belts. Generally speaking, when coal is being picked on ordinary belts one hand is employed in pushing the coal about, whereas on these conveyors both hands can be employed picking out the refuse. The power required to drive this type of screen or conveyor is regulated by the length of the trough and size of the perforations introduced, but, generally speaking, a 60-ft. screen requires from 10 to 12 H.P. under a full load. In a plain trough it is possible to convey 325 tons per hour, and only absorb from 8 to 10 H.P., where there are no perforations to obstruct the travel of the coal.

This system of conveying, screening, and picking is largely used, and Fig. 169 shows a Marcus conveyor 78 ft. long and tapering in width, with a capacity of 150 tons per hour, classifying the coal into four sizes, three of which are conveyed by cross conveyors of the same type running at right angles to it. Of late a modification of the Marcus conveyor has also been employed for washing coal.

COMBINED ELEVATORS AND CONVEYORS

CHAPTER X

GRAVITY BUCKET CONVEYORS

THE principle underlying this type of conveyor is utilised not only for handling material in bulk, but also for larger individual loads in a horizontal and vertical direction. Conveyors for the former purpose are generally described as:—

Gravity Tipping or Tilting Bucket Conveyors.—Generally consist of two endless chains or ropes held at fixed distances apart by suitable bars, which are fitted with small rollers at each end. Every link, or sometimes every second link, carries a bucket, so that the whole is an endless and unbroken chain of buckets, which are not, however, fixed like elevator buckets, but are movable and suspended above their centre of gravity.

When this conveyor is at work the buckets will always be in an upright position, whether they are moving horizontally or vertically. Each bucket carries its load to the point at which its delivery is required, and here it is generally met by some adjustable tripping device which tilts each bucket in turn, and thus empties the contents.

The gravity bucket conveyor is of American origin and enjoys great popularity; the details of some of the best forms have been most carefully designed. Where coal has to be conveyed to overhead bunkers in boiler-houses, this kind of conveyor certainly has great advantages. Instead of using a separate conveyor to bring the coal from the railway sidings and installing an elevator to raise it to the level of the bunkers, at which point a second conveyor must be used to distribute the coal from the elevator to the different compartments of the bunkers, one gravity bucket conveyor will perform these three operations, while sometimes the returning and therefore empty strand of buckets is used to convey the ashes away from under the boilers. Opinions differ concerning the advisability of this practice, as it is sometimes argued that the handling of corrosive ashes, which by the way only represent 10 to 15 per cent. of the coal, is detrimental, and will shorten the life of an equipment which with ordinary care would last for many years if used for coal alone.

The driving gear is in some cases not unlike that of the ordinary chain-driven elevator, but more often it is independent of the conveyor, and actuates it by a series of pawls attached to a wheel, each of which pushes the conveyor forward, link by link. Or sometimes there is a wheel, with suitable projections, which are of the same pitch as the buckets, and which gear, as it were, into a portion of the continuous chain of buckets either on the inside or on the outside of the strand.

The devices for loading each of the buckets without spilling the material are of great importance in this type of conveyor. They are very numerous, and are fully detailed later.

Figs. 170 and 171 show portions of two early types of the gravity bucket conveyor, the "Hunt" and the "Bradley."

The speed of travel of these conveyors is slow, and the necessary capacity is obtained by installing buckets of a size corresponding to the load to be conveyed. The normal rate of travel is 40 ft. per minute, but it can be either increased or decreased within

limits of 25 and 50 ft., according to circumstances. The power required is comparatively small, and depends to a large extent on what proportion of the length is used for elevating.

A conveyor of this type offers the undoubted advantage of handling material in the gentlest possible manner. One main drive is sufficient for an entire installation. The material can be fed to or withdrawn from the conveyor at any point. But it has this disadvantage, that if one portion of the installation breaks down, the whole is at a standstill; whereas, if different appliances are used for elevating and conveying, a portion of the whole may sometimes be used as a makeshift. Moreover, there are a large number of journals to be lubricated and kept in repair. The former operation is, however, automatically effected in some of the best conveyors.

The Hunt Conveyor.—The Hunt conveyor, the invention of C. W. Hunt, which was probably the first successful one of this class, consists of

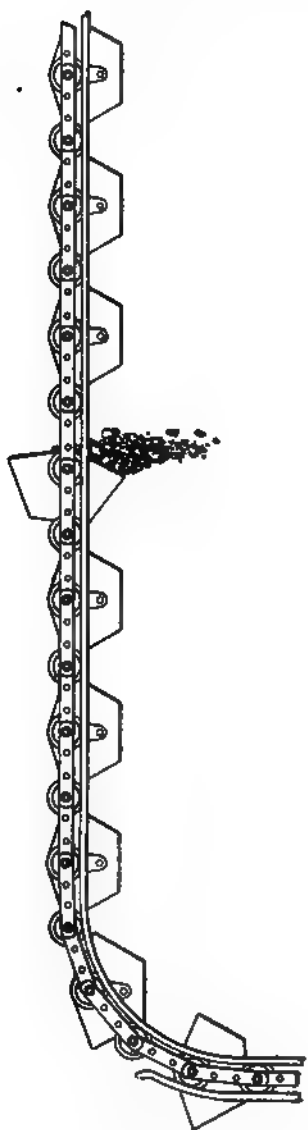


Fig. 170. The Hunt Conveyor.

a series of pivoted buckets suspended in such a manner that they maintain their vertical position, and are free to revolve on their axes at all points of their path except at the place in which they discharge, this operation being effected in a very simple and efficient manner by means of a cam action, whilst the buckets on being released right themselves and are ready to be refilled. The buckets pass through the cycle of their motions continuously, filling and emptying at any given points, the discharging being so simply performed that

by merely moving a lever the contact can be made or broken. The action is complete, the buckets being so tipped that nothing is allowed to remain in them after they pass the discharging point.

The chain is centrally supported and centrally driven, the wheels being placed between the links of the chain, while each alternate pair of wheels has an axle traversing the space between the two chains and correctly maintaining the distance between them, thus preventing distortion or alteration of the track gauge.

The buckets are suspended on pivots projecting from the inner side of the chain, and are so arranged that by withdrawing two pins each bucket can be removed from the conveyor without disturbing any other part.

The wheels are so made that each will carry enough lubricant to provide for a certain period of running without attention.

The track consists of a special section of headed rail, joined together in convenient lengths by double fish plates, securely bolted through the rails, and resting upon cast-iron standards, to which the rails are bolted by means of hook bolts, obviating all drilling of holes, and consequent reduction of the rail section.

The curves which change the direction of the movement of the buckets are, as far

Fig. 171. The Bradley or Pan and Bucket Conveyor.

Fig. 172. General Arrangement of Pan and Bucket Conveyor.

as possible, formed as free wheels. Each pair of wheels is bored, turned, and keyed on a steel spindle, running in bushed and automatically lubricated bearings. The wheels of the conveyor chain are thus at rest and move round with the curved wheel rims, thus minimising friction and preventing wear at these important points where the stress is greatest on the conveyor chain.

By this improved and combined provision for movement a great reduction in the driving power has been effected. The tightening curve is provided with side-blocks and tension screws, which enable it to be moved so as to take up any slack in the chain which may be formed.

The automatic continuous filler consists of a short endless chain, carrying seven funnels and supported in a frame, the funnels successively covering the buckets of the conveyor, and as the filler chain is driven by contact with the conveyor chain, the spacing and filling is accurate and uniform. These funnels and chains move round an oval track formed in the filler frame, and are supported on wheels similar to those of the conveyor chain.

The driving gear is so designed as to propel the chain by means of pawls which successively engage with the cross studs of the chain (see Fig. 170) and give a central thrusting action. The two parts of the chain are driven equally and simultaneously.

The Babcock & Wilcox Gravity Bucket Conveyor.—This is also on the original Hunt system, but improved in details. To begin with, the chain links are bushed and the supporting rollers are carried on the bushes, and the parts are not only interchangeable, but the axles and bucket studs are also reversible, and in practice it has been found that where lubrication is well attended to during the earlier stages of the installation, fine smooth surfaces are obtained in all the wearing parts of the chain. Each bucket is stamped out of one sheet of mild steel. The driver and wheel curve bearings are now made self-aligning, with larger bearing surfaces, consequently binding and extra friction is avoided in the driving gears and shafting.

For complete installations of this conveyor see Chapters XL. and XLI.

The Bradley or Pan and Bucket Conveyor.—This is the design of W. H. Bradley, of the Consolidated Gas Co. of New York, and is built by the Steel Cable Engineering Co., of Boston, U.S.A., and others. It consists of a continuous trough built in sections, and supported on axles and guide wheels running on suitable rails. There is one axle to each segment of the trough, and in each segment a bucket is pivoted to the sides.

The axles are securely clamped to two endless steel cables instead of the chains which are generally used on conveyors of a similar type. This conveyor can be loaded when ascending, in which case the material is fed from a spout, and the process is similar to the feeding of an elevator. Material can also be fed at any point on the lower horizontal strand, as the conveyor itself consists of an endless trough similar to a continuous trough conveyor. Thus, when the conveyor runs horizontally, the endless trough receives the feed; but as soon as the ascent begins, each short section of trough empties itself into its respective bucket, so that when ascending the buckets are separately suspended from their pivots, and the trough runs empty at the side.

The discharging of the buckets is performed by a tipping device which can be so set that the contents of the buckets can be discharged at any desired point. The upper surface of the tipping gear is slightly corrugated to give the bucket a jarring motion, which shakes out any material that might otherwise adhere to the sides.

Fig. 172 gives a general outline of such a conveyor when receiving coal. The illustration shows on the left the railway truck which brings the coal and takes away the ashes. The truck is preferably self-unloading, and beneath it is shown a coal-

breaker which reduces the coal to a more uniform size, and then delivers it in a regular feed to the ascending buckets of the conveyor, which deposit it in the bunkers over the boilers.

The return portion of the conveyor, when not in use for carrying coal, can be used for removing the ashes. One of the boilers is shown in the illustration, from which it will be seen that the ashes are collected in hoppers which deliver in

Fig. 173. Position of the Pans and Buckets on the Upper Strand.

a similar manner to those beneath the coal-breaker, so that the ashes can be deposited into the conveyor whenever it is available for this purpose. They are then discharged just above the hopper, from which the contents can be loaded into trucks at intervals. The illustration clearly shows the driving gear, the feeding and tipping devices, as well as the arrangements for keeping the chain taut.

The buckets of this conveyor are made of stamped steel. In the continuous pan section there are no joints whatever, as the sections can be bent out of one piece, and overlap each other to prevent leakage. They depend for their alignment with each other upon the wheels and axles upon which they are supported, and for their pitch upon the cables which connect them.

Fig. 174. Position of Pans and Buckets on the Lower Strand.

Each bucket is provided with a small roller which is used for its discharge. It is claimed for this conveyor that it is very easy to replace any portion should this be necessary, as the clamps by which the axles are attached to the cables are fully accessible along the entire upper strand. This will be seen from Fig. 173, which shows a portion of this pan and bucket conveyor in position on the upper strand.

Fig. 174 shows a portion of the same conveyor on the lower strand.

Fig. 175 represents the ordinary feeding device, from which it will be observed that spilling is impossible, as the conveyor forms a continuous trough, so that what one bucket misses must drop into the next one.

Fig. 176 illustrates a similar feeding device used with material of a slightly sticky nature, an attachment giving the delivery spout a slight shaking to prevent clogging.

In Fig. 177 the conveyor is erected in a tunnel with two skirting plates over, so that the coal or any other material to be conveyed can be thrown into the conveyor from the floor on either side.

An inherent weak point of this design is the employment of wire ropes, which it is difficult to keep and adjust to be of identical length. No such installation is in use in this country so far as the writer is aware.

The Link Belt Company's Conveyor (known as the "Peck" carrier).—Fig. 178 shows the manner in which the buckets manufactured by this company are overlapped, as an expedient to prevent leakage at the loading point. It will be seen from the illustration that the overlapping is obtained by suspending the buckets at extensions of the links of the chain, instead of from the usual support at the pin of the chain, so that in passing round a corner wheel the buckets travel in a larger circle than the chain. The illustration shows that as soon as the link begins to bend over one of the corner terminals, the point of suspension of the previous bucket is raised above its neighbour, so that the buckets gently disengage themselves from their overlap without in any way knocking against each other when negotiating corners.

Fig. 175. Feeding Device for Pan and Bucket Conveyor.

The following table gives the dimensions, capacity, and speed of this conveyor:—

Bucket.	Pitch of Chain.	Carrying Capacity of Bucket in Cubic Feet.	Capacity in Tons of Coal per Hour.	Speed in Feet per Minute.
Inches.	Inches.			
18 × 15	18	0.68	15-20	30-40
18 × 21	18	0.94	20-30	30-40
24 × 18	24	1.68	40-50	40-50
24 × 24	24	2.24	55-70	40-50
24 × 30	24	2.80	75-100	40-50
24 × 36	24	3.36	90-120	40-50
30 × 24	30	3.50	95-120	45-60
30 × 30	30	4.37	110-160	45-60
30 × 36	30	5.25	140-180	45-60
36 × 36	36	8.50	210-330	50-80

The Bar-Link Conveyor.—This conveyor, which is built by the Steel Cable Engineering Co., is another form of the tilting bucket conveyor, and has the buckets so arranged that they can be loaded at any point on the lower strand without the necessity of employing a loading device. Any spilling between the buckets is prevented by placing an additional axle, and guide pulleys between each pair of buckets, the extra spindle being in such a position that when the buckets are on the lower run it covers the space between each pair. The buckets are held in position while being loaded by a roller attached to each one, which travels on a separate guide rail, as shown in the illustration. These rollers will also keep the bucket in position upon the upper strand, and during the process of discharging.

The axles are connected by steel bar links, and the guide wheels are fitted with self-lubricating attachments. The illustration (Fig. 179) shows all the corner guides, as well as the loading and discharging devices and the driving gear.

Swinging Bucket Conveyor.—The swinging bucket conveyor (Fig. 180) is similar to the Bar-Link Conveyor just described, with this difference, however, that the buckets are suspended at one end instead of in the centre. This arrangement is intended to facilitate their discharge. During conveying on the lower run the buckets are held in a horizontal position, and so readily receive the feed. The illustration shows the feeding device, the delivery and the attachment for turning the buckets over into

Fig. 179. Feeding Device for Sticky Material with Pan and Bucket Conveyor.

their original position, as well as the automatic tension gear.

Continuous Bucket Conveyor.—A type of conveyor which empties itself not by tilting the bucket, but by opening it, is the continuous bucket conveyor built by the Steel Cable Engineering Co., of Boston. The buckets in this case are divided longitudinally, and hinged for the purpose of discharging. The conveyor itself is used in a similar manner to other travelling or tilting bucket conveyors. It will therefore suffice to show the bucket in its delivering position only. This is represented in Fig. 181.

There is a diamond-shaped frame made of round iron bars, with which the buckets engage when approaching it. This opens the halves, and allows them to close gently as the bucket passes off at the other end.

The Humboldt Conveyor.—A Continental development of the system is the

Humboldt gravity bucket conveyor, which was designed to overcome the drawback of other conveyors of similar type, namely, inability to work except in one plane, or at least with only a very slight deflection. It is claimed for the Humboldt conveyor that it will go

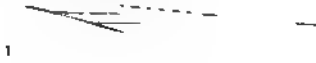


Fig. 177. Pan and Bucket Conveyor receiving Feed from Floor on either Side.

round any incline backward and forward in both planes, and that it is therefore adaptable for installations where the ordinary travelling bucket conveyor would be useless, or where more than one would have to be used, and the material transferred

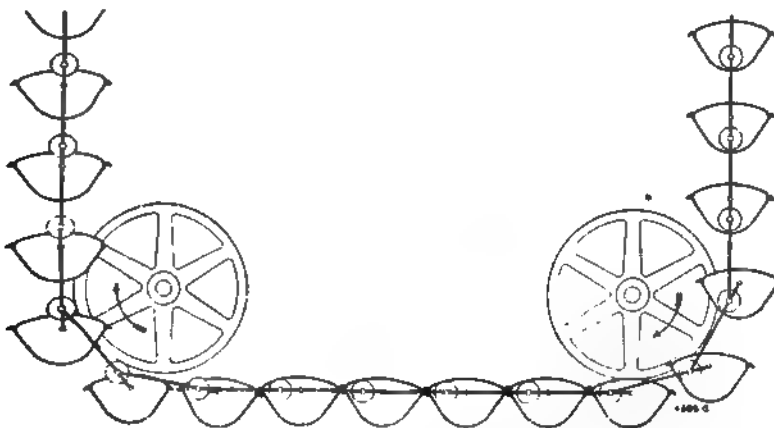


Fig. 178. Gravity Bucket Conveyor with Overlapping Buckets.

from one to the other. The conveyor under consideration consists of a number of miniature carriages, which are each fitted with two spindles and four wheels. The carriage resembles a small contractor's truck (see Figs. 182 and 183); it is pivoted above its centre of gravity, round which pivot it can be tilted. The trucks are coupled together by a central coupling bar, and these coupling bars allow not only of an upward and downward motion, but also of a side movement within certain limits. The conveyor is

Fig. 179. General Arrangement of Bar-Link Conveyor.

Fig. 180. General Arrangement of Swinging Bucket Conveyor.

supported on a pair of rails similar to other conveyors of this type, and where curves have to be negotiated there must be a second pair of rails above the wheels to guard against derailment. The axles are provided with sufficient lubricant to last for several months.

The pitch of the buckets—being necessarily large for these conveyors—influences the dimensions of the driving drum, which must be larger than that of other conveyors of the tipping bucket type.

As the buckets must be some distance apart, to allow sufficient freedom when going round curves, it was necessary to have a special feeding device. This consists of an outlet controlled by a valve which opens automatically every time a bucket presents itself beneath it, and as the buckets can be set further apart for elevators of small

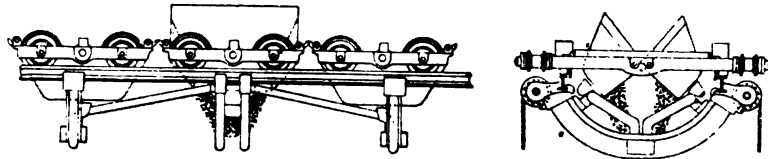
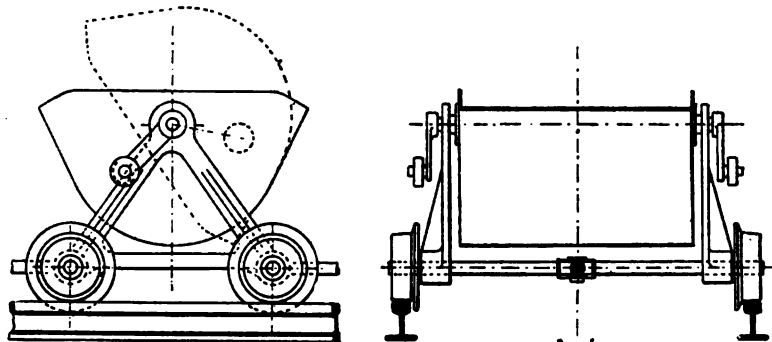


Fig. 181. Portion of Continuous Bucket Conveyor.

capacity, the opening of this slide can be set to suit any pitch of buckets. On the other hand, should a higher capacity subsequently be required in any installation, the buckets can be set closer together, and thus the filling machine is correspondingly altered to suit the pitch of the buckets. Such intermittent feeding devices present no difficulty for small material, but for large coal they would be a decided hindrance



Figs. 182 and 183. Humboldt Conveyor.

to the efficiency. (This applies to all conveyors where the buckets are not close together.) These buckets are emptied in a similar manner to those already described. This type of conveyor is reported to be successfully at work in several boiler-house installations, as well as for coaling locomotive engines. It is built in six sizes for gauges of 20, 24, 28, 32, 36, and 40 in., with a capacity for each bucket of $\frac{1}{4}$ to $\frac{1}{2}$ cwt. of coal. The buckets are placed at a pitch of 20, 30, 40, and 50 in., and it is claimed that a capacity of over 100 tons per hour can be reached. It is said that the speed can be varied from 30 to 100 ft. per minute. There seems, however, no apparent reason why this particular conveyor should run faster than any other swinging bucket conveyor, to which type it closely conforms. It is built by the Humboldt Engineering Works Co., of Cologne.

The Schenck Conveyor.—This is shown in Fig. 184. It differs in many

respects from other known conveyors of the gravity bucket type. The point of suspension is in the same plane as the centre of the chain and not above, as in the Humboldt conveyor, and the units have only one pair of wheels and only one axle, which latter serves also as the link bolt of the chain. It is claimed for this conveyor that little power is required to drive it, and that by the special construction of the buckets and links it can move in any direction and plane, and the strand of buckets can even be twisted when a change of direction to a new plane is required. If this twist is not necessary for the general arrangement of the conveyor, a coupling bar takes the place of the small swivelling muff couplings which are shown in the illustration. The illustration also shows the detail of the bucket with its single axle, its substantial frame, the hinge-like attachment on the axle, and the couplings between the buckets, the whole being designed to withstand the greater strain caused by the altered conditions of arrangement of these conveyors.

The buckets are comparatively light, but strong, a piece of gas pipe covers the axle, and is secured by two small castings to the sides of the bucket. The method of lubrication is shown in Fig. 185. κ is a kind of Stauffer cup which screws on to a boss of the runner wheel R either by hand or by the arrangement indicated in Fig. 186. When the grease is entirely used up the lid has left the thread, and therefore hangs loosely over the boss, so that the attendant can readily see when it has to be refilled. The Stauffer can also be tightened automatically whilst passing over the terminals, as will be seen from Fig. 187.

A considerable amount of power may have to be transmitted through curves in long conveyors. This means the creation of side stresses, which affect the frame and the wheels of the units, and the construction of these details must therefore be more substantial in this type of conveyor than in those which travel in a vertical plane only. Fig. 187 shows the driving gear with a large drum directly connected to an electric motor by means of worm reducing and spur gearing.

A feeding device for a conveyor of this type is shown in Fig. 188; the design is,



Fig. 184. Schenck Gravity Bucket Conveyor.

Figs. 185 and 186. Showing Methods of Lubricating.

however, varied somewhat according to the size of the material to be fed. The action is as follows: the slide s closes the feeding hopper T , and opens the same intermittently whenever a bucket is underneath ready to be charged; the opening of the slide s is performed by the running rollers R of the conveyor chain coming in contact with the two

levers *H* (one at each side of the chain). The illustration shows one of the buckets just at the point of contact with the levers *H*, and therefore beginning to open slide *s* for charging the next following bucket. As soon as the levers *H* have reached the position marked by the dotted line, the levers are released by the rollers, and the springs *F* and dashpot *P* close the slide again gently.

The tipping device is shown diagrammatically in Fig. 189. Such devices may be used either at one or more predetermined points, or they may be mounted on wheels and

rails, so that they can be used at any point of the horizontal strand of the conveyor running over the bunkers. The diagram shows the tipping device in two positions, the first in action and the second out of it. *A* is the tripper; it engages with the small rollers on each of the buckets which it tilts up to empty. To put the tripper into action the chain *z* is pulled, which by levers *a*, *b*, *c* raise the tripper *A* into position, where it is retained by the catch *H*, levers *e* and *f*, and weight *G*. All passing buckets

Fig. 187. Driving Terminal of Schenck Conveyor with Motor.

are now emptied until the bunker is nearly full and the coal reaches flap *K*, when any further coal arriving pushes this flap in the direction of the arrow. This motion of the flap releases catch *H* by levers *c* *d* and *e* *f*, so that the next bucket pushes the tripper *A* over into the second position, and the buckets pass full to the next point of delivery.

A number of Schenck coaling plants have been erected in recent years, and some of these have conveyors of over 1,000 ft. in length, with a capacity of 35 tons per hour.

Fig. 190 illustrates part of a complete installation, which gives a good idea of the flexibility of the conveyor. The two bottom or loading terminals are for coal or ashes, as the case may be. The outward extension about half-way up shows how the discharge may be effected at an intermediate point, and in the upper portion of the illustration the main delivery into the bunker is shown; here the conveyor runs at an angle of 90° to the portion receiving the load at the lowest end.

Prevailing conditions have often made gravity bucket conveyors with universal movements indispensable, as with them a whole coaling installation can be served by one conveyor, instead of by several such devices in conjunction with elevators.

The Bleichert Conveyor.—In this conveyor flexibility in all planes is achieved in an entirely different manner. In the first place, the double rail track is dispensed with,

Fig. 188. Feeding Device for Schenck Conveyor.

which is probably one of its best features, as this tends to make the strand of the conveyor more flexible for curves on a horizontal plane, and each unit has only one running rail in the central direction of the chain.

It will be seen that with such an arrangement the strand of the conveyor chain is in lability, so an auxiliary rail above the wheels becomes necessary for guiding the rollers in their horizontal passages at top and bottom (the vertical portion, of course, requiring no rails whatever). This construction makes it imperative that the buckets should be divided into two compartments, one on either side of the central roller (see Fig. 191)

This development offers rather more difficulty at the loading point, particularly in conveyors of small capacity, where the units are not close

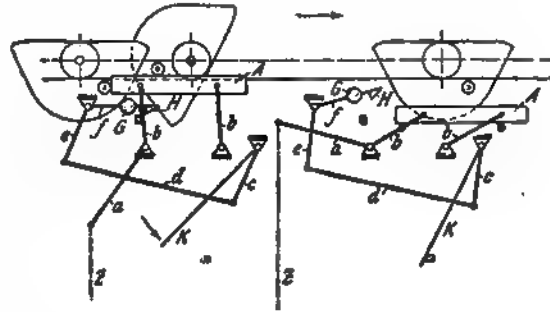


Fig. 189. Diagram showing Method of Tipping.

together, as two shoots are necessary, one for each section of the bucket. The same circumstance makes this system impracticable for plants of very small capacities, as each of the two buckets forming one unit would be too small in such a case. The links of the chain are composed of two D-shaped bars which surround the rollers, so that the two open ends *aa* and *bb* meet in the centre and are traversed by the axle of the roller, which forms at the same time the pin for the chain, and carries a bucket at each of its overhanging ends.

The closed ends of the D-shaped link segments of each unit are joined together by a short

Fig. 190. Showing Portion of Complete Installation of Schenck Conveyor.

swivel link connection which permits flexibility in all directions. The delivery at the top is similar to the methods adopted by the Hunt and other conveyors of this type. An installation of this kind, with a capacity of 100 tons of coal per hour, a chain of 284 yards in length, and with a lift of 35 yards, takes only about 15 H.P., an exceptionally low figure, undoubtedly due to the single rail and consequent reduction of friction.

There are several other designs of conveyors of the tilting bucket type, which do not, however, present features sufficiently distinctive to entitle them to separate descriptions.

The Link Belt Company build a similar apparatus. It has the form of an ordinary elevator with V-shaped buckets supported symmetrically by two chains (see Fig. 192). For the transport in a horizontal direction the buckets act as scrapers in the troughs provided for the upper and lower runs.

The illustration shows how the buckets elevate the coal and push it along the horizontal carrying run until discharged through gates in bottom of trough. The length

of the horizontal run can be increased as desired up to the limit of the strength of the chains, and gates added as may be necessary.

The elevator described and illustrated on page 18 can also partly be classed under this chapter, as it will convey horizontally on the bottom strand, but the delivery is confined to one point.

Continuous Travelling Trough Conveyor with Partitions.

—This conveyor has much in common with the continuous trough

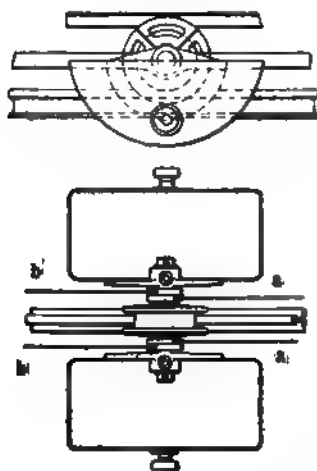


Fig. 191. Bleichert Gravity Bucket Conveyor.

conveyor, but as it both elevates and conveys the material, it has been included in this chapter. It can be used not only for conveying on a level, but will also admit of conveying up inclines, and will even work in a vertical position. A conveyor of this type is built by the Steel Cable Engineering Co., under the name of the rigid partition conveyor. It is driven, like most of their conveyors, by steel cable, and each section of the trough has its own guide wheels, which run on suitable rails, as shown in Fig. 193. The discharge is similar to that of an ordinary bucket elevator.

Each section has a partition across its lower portion which forms a kind of bucket. The illustration shows the feeding of the conveyor at the level portion, the material being fed on in the same way as it is on the pan and bucket conveyor. It is used for minerals, coal, etc., and is also employed to handle coke which has been quenched but is still hot.

Fig. 194 shows a portion of the same kind of conveyor in a horizontal and vertical position. The feeding device and delivery shoot are clearly seen, as well as the automatic tightening gear for keeping the steel cable taut. Unlike Fig. 193, the discharge of this kind of elevator and conveyor combined takes place on the lower strand. A

trough, therefore, must be provided for the horizontal portion of the lower strand. This trough is fitted with doors or slides, so that delivery can be given at any desired point. In the case illustrated, the delivery is given by a horizontal door held in position by a chain. This can be closed, and some other door opened elsewhere. The partitions in the buckets act like the scraper plates of a push-plate conveyor in this trough.

Conveyors for Handling Larger Individual Loads in both Horizontal and Vertical Directions.—Appliances on the same principle as the gravity bucket conveyor are often used for tea chests, barrels, cases containing cube sugar, soap, etc., as long as they are all of a uniform size.

By a slight modification to a vertical swing tray elevator be readily adapted for conveying goods

Fig. 192.
canals

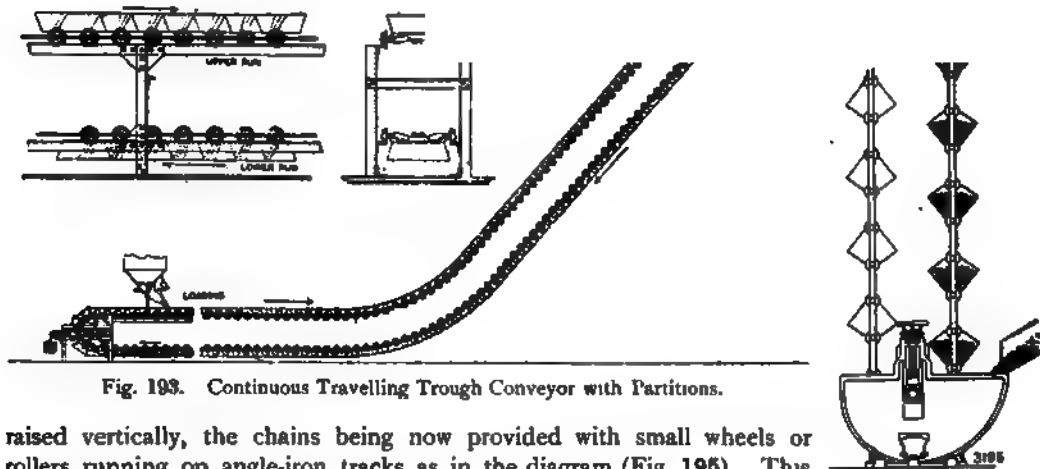


Fig. 193. Continuous Travelling Trough Conveyor with Partitions.

raised vertically, the chains being now provided with small wheels or rollers running on angle-iron tracks as in the diagram (Fig. 195). This results in an enormous extension in the scope and utility of the machine, which further emphasises its marked superiority over the intermittent cage hoist, for the movement of large quantities of similar packages.

It is evident that the path of the chains is not confined to the vertical and horizontal directions. The path may be inclined at any angle, or even curved, a variety of possible combinations being thus available. The nature of the path is determined by the site, the relative positions of the machines and workers to be served, and the impediments to be cleared. Of necessity, every conveyor has to be designed specially to suit the local conditions and requirements. Standardisation and production in quantities are clearly impossible in the case of conveyors where no two are precisely alike in form and dimensions, although certain details, such as chains, have been standardised.

An interesting example of such a type of conveyor is illustrated in Fig. 196. It is for the purpose of handling skips containing cops of cotton yarn to and from the conditioning cellar in the spinning mill of Messrs Eckersley's, Ltd., Wigan. The conveyor was built by the Ewart Chain Belt Co., Ltd., of Derby.

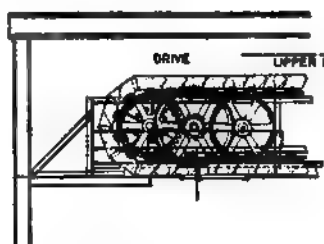


Fig. 194. Continuous Trough Conveyor with Partitions in a Vertical and Horizontal Position.

It will be noticed that the path of the chains is one of considerable complexity; indeed, the entire conveyor is unique of its kind. It runs continuously ten hours per day, and is now found to be indispensable. The speed is about 40 ft. per minute, and the carrying capacity 150 skips per hour, weighing 90 lb. each, with the swing trays 16 ft. apart. The swing tray bottoms are of hard wood, and measure 3 ft. 9 in. by 2 ft. 2 in. The two strands of chain have a total length of nearly 1,000 ft.; and yet the

[To face page 140.]

whole conveyor can be driven by a belt $1\frac{1}{2}$ in. wide, the power absorbed being unexpectedly small. The skips travelling in one direction from the spinning rooms to the conditioning

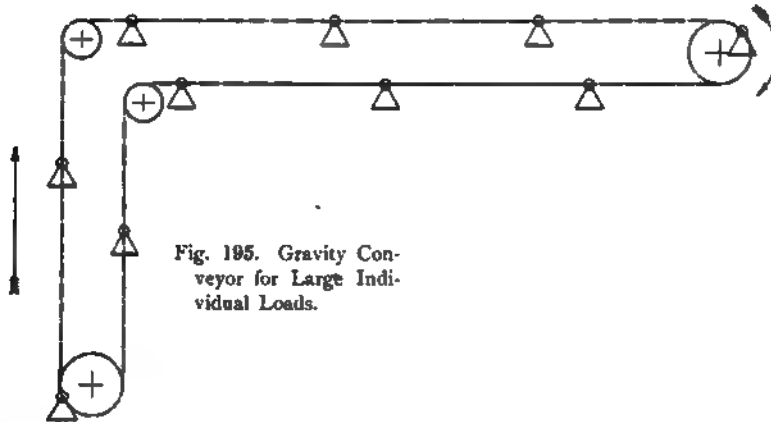


Fig. 195. Gravity Conveyor for Large Individual Loads.

cellar, balance those returning in the opposite direction to the winding room, where they are taken off by lads. Thus the resistance is chiefly frictional.

By providing finger trays on the chains and special grids at the feeding and discharge points, it is often feasible to arrange for the automatic picking up and delivery of packages. An example with the adoption of the finger tray system is given in Fig. 197. This takes bundles of loose newspapers from the printing room to the dispatch room of a London daily paper. Here, on account of the available floor space in the printing room being limited, it was necessary to run the conveyor in a tunnel below the floor, a cross section being shown in Fig. 198. The carriers are 6 ft. apart, and the capacity of the machine is twelve bundles per minute, or 720 per hour, equal to about 173,000 copies per hour. It runs night and day with intervals of rest.

This analysis of the different types of package conveyors will be concluded by reference to a special form of pivoted or tipping carrier conveyor, provided with discharging mechanism, which can be thrown into gear at pleasure for tipping out the contents of the carriers at several delivery points, as shown at A, B, and C in Figs. 199 and 200. It was erected in the year 1907 for the Gourcock Ropework Co., Ltd., Port-Glasgow, for conveying bobbins 8 in. diameter and weighing 13 lb. each, at the rate of 400 per hour. The length is about 150 ft.

between the terminals, and it is driven by a 5 H.P. electric motor. It proved so successful that a second conveyor of the same type was installed in the following year.

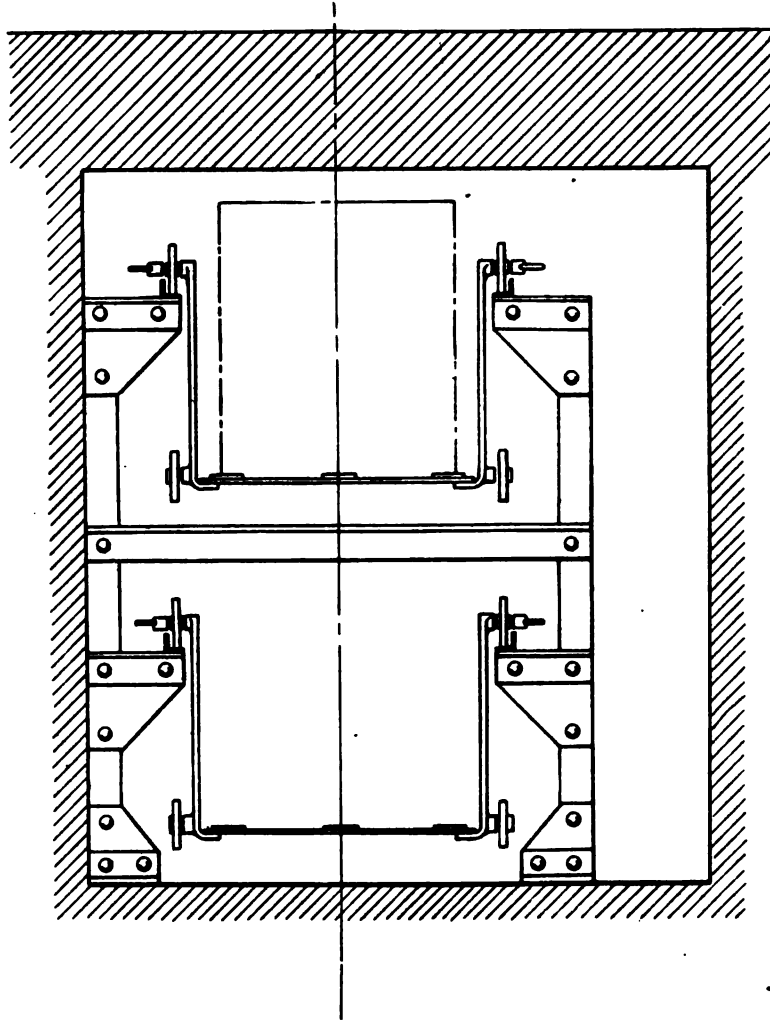
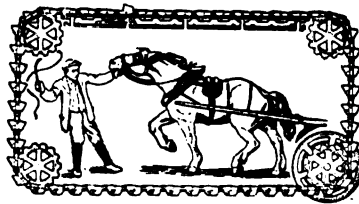


Fig. 198. Cross Section of Swing Tray Conveyor.

With this form of conveyor it is feasible to discharge light packages not only from the descending carriers, but also from the ascending carriers and those moving horizontally. This installation was erected by the Ewart Chain Belt Co., Ltd., of Derby.



es tipped out.)

[To face page 142.

CHAPTER XI

SUMMARY OF DRIVING POWER, SPEED OF TRAVEL, AND WEAR AND TEAR OF ELEVATING AND CONVEYING MACHINERY

Driving Power Required for Different Types of Conveyors.—In order to afford an easy comparison between the driving power required by the conveyors described in the preceding pages, the table given below has been compiled. It gives the Horse-Power per hour of different conveyors for loads of 50 tons and lengths of 100 ft.

	Horse Power.
Band conveyor for grain - - - - -	4·8
" " minerals - - - - -	5·0
Zimmer conveyor (balanced) - - - - -	7·75
" " (unbalanced) - - - - -	8·75
Push-plate conveyor - - - - -	12·8
Worm conveyor - - - - -	25·0

Push-plate conveyors of the same dimensions and capacity, when fitted with a pair of wheels on each plate and well lubricated, may take only about 5 H.P., but this depends almost entirely upon the lubrication.

Some difficulty has been experienced in obtaining reliable data concerning the power consumed by conveyors, but the figures given above may be relied on for practical purposes.

COMPARATIVE RATES OF TRAVEL OF THE DIFFERENT TYPES OF CONVEYORS¹

	Average Speed.
Band conveyor (for grain) - between 250 and 700 ft. per minute	475
" " (for heavy material) " 150 " 700 " " "	425
Push-plate conveyor - " 50 " 180 " " "	115
Trough cable conveyor - " 100 " 120 " " "	110
Travelling trough conveyor - " 60 " 120 " " "	90
Zimmer conveyor - " 40 " 60 " " "	50
Worm conveyor - " 40 " 60 " " "	50

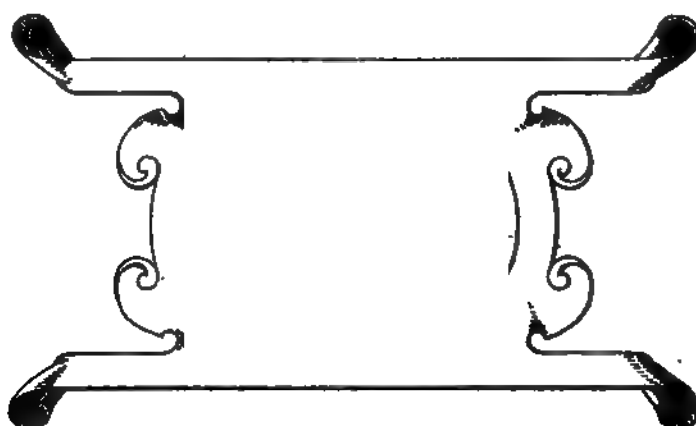
Wear and Tear of Elevating and Conveying Machinery.—It may be of interest to compare the cost of upkeep of elevating and conveying plant of different types given in the following table.

With the exception of the last item, this table has been compiled by the late Mr W. R. Chester, of Nottingham, who, as engineer to the Nottingham Gasworks, tabulated this valuable information from plant under his personal supervision.

¹ The above speeds are taken from conveyors in actual work, but the author can see no reason why push-plate, trough cable, and travelling trough conveyors should not run at 60 to 180 ft. per minute.

The last item in the table was furnished by Mr Weiss, the engineer of the Zürich Gasworks, where several Zimmer-type conveyors have been at work since 1898.

Apparatus.	First Cost.		Tons of Material Trans-ported.	Distance of Traversa.	Cost for Repairs and Renewals.			Description of Material Con-veyed.
	Total.	Per Foot Run.			Total.	Per Ton.	Per Ton for 100 Ft. of Traversa.	
Elevator - -	£ 1,554	£ s. d. 4 4 0	335,237	Feet 74	£ s. d. 86 1 6	0.001	0.082	Coal.
" - -	819	6 6 0	178,541	58 & 72	679 6 8	0.013	1.000	Partially hot coke.
" - -	428	5 7 0	37,685	40	7 4 0	0.005	0.115	Oxide of iron and lime.
Push-plate conveyor	296	2 9 4	149,350	30	70 6 0	0.113	0.377	Coal.
" "	1,486	5 3 11	29,769	{ 90 90 106 }	110 11 3	0.891	0.938	Hot coke.
Plate-belt conveyor -	2,026	3 12 6	149,350	{ 125 125 125 60 }	2,311 0 0	3.714	2.070	Hot coke.
Canvas band - -	443	4 10 0	say 10,000	98	40 0 0	say 1.00	say 1.00	Small coke and breeze
Band conveyor -	296	2 9 4	149,350	30	70 6 0	0.113	0.377	Coal.
" "	172	1 11 3	2,180	110	42 1 1	0.05	4.21	Sulphate of ammonia.
Zimmer conveyor -	1,767	1 0 6	260,000	{ 21 conveyors. Total length 1,722 ft. }	15 0 0	0.114	0.0009	Coal.



CHAPTER XII

THE HANDLING OF HOT COKE IN GASWORKS

THE substitution of machinery for manual labour in the conveyance and handling of hot coke in gasworks, coke-oven installations, and elsewhere, presents many special difficulties, owing to the hard and friable nature of the material, and its more or less incandescent condition. Its cutting nature gives rise to severe wear and tear of the conveyor and its trough, and any roughness in handling causes considerable loss by the production of coke dust or "breeze," which is not only worthless, but, moreover, enters the joints of chains and other moving parts, and grinds them away, even when the coke is being quenched with water, as in that case the water is apt to wash the small gritty particles on to the wearing surfaces. The sudden changes of temperature to which the conveyor is moreover subjected, produce expansion and contraction, causing warping and buckling of the conveyor or its parts.

From an economical standpoint, the substitution of machinery for manual labour in handling coke does not present the same advantages as in the case of coal, principally because the wear and tear is so much greater, necessitating much heavier and more costly machinery, so that mechanical coke-conveying plants can only be recommended for relatively large establishments. The cost of the hand labour involved in quenching, carrying, and stacking coke will depend largely on the amount handled annually. In pre-war days it has been known to cost 1s. per ton, and now even 1s. 3d., but under the most favourable circumstances a man can remove hot coke from the retort house of a gasworks to the coke heap at the rate of about 15 tons per day. To his daily wage would have to be added the cost of repairs and renewal, interest on capital outlay, etc., which would be about 1d. per ton of coke dealt with. According to the calculations of the late Mr W. R. Chester, M.Inst.C.E., who had years' experience with conveyors for handling hot coke, the average cost of repairs and renewals for a conveyor 100 ft. in length was 1½d. per ton of coke handled. The cost of such a conveyor would be, approximately, £600, and as it would be capable of conveying 30,000 tons of coke per annum, 5 per cent. interest on the capital outlay would represent about ¼d. per ton of coke conveyed. The driving power for such a conveyor would depend very much upon its state of repair, but allowing ¼d. per ton it may be assumed that the total cost, including driving power, would not exceed 2d. per ton of coke handled. It should be taken into consideration that in conveyors of the most modern type the wear and tear and the driving power consumed would be less than in those of the Nottingham Gasworks, on which Mr Chester based his calculations, in 1901.

According to Alwyne Meade, M.I.C.E., engineer of the Wapping Gasworks, the cost of handling coke by manual labour, at present-day (spring 1919) wages, will amount to 1s. 7d. or even 1s. 9d. per ton, in a works producing annually 30,000 tons of coke. As regards the cost of handling by machinery, Mr Meade says that at present prices this will amount to 6½d. per ton, to which should be added a further 3½d. per ton, to allow for interest on capital expenditure, etc.

In the method of removing coke by hand usually employed in gasworks, with horizontal retorts, one man rakes the coke out from these into a barrow placed under the

mouthpiece, whilst a second man quenches it with water from a hose or bucket, after which the coke is wheeled out of the retort house into the yard. Where inclined retorts are used, the coke falls out by gravity and requires but little assistance.

The first improvement on this method was the adoption of cage-like tipping-barrows or trucks, running on narrow gauge rails either in front of the retorts or on the furnace floor below. The hot coke is discharged directly into these trucks, in the latter case through suitable openings in the floor, each truck generally holding the contents of one retort. The truck is then pushed outside the retort house, and the coke is there quenched with a spray of water, the truck meanwhile standing over a grating connected with a drain which leads away the surplus water. Above the truck is an inverted funnel with an uptake to lead away the fumes and vapour. When the coke is completely quenched, the truck is pushed to the coke heap and its contents are there tipped, or sometimes the trucks are elevated by a lift to the upper level of the coke hoppers or stock heap, where they proceed by overhead rail tracks and are discharged on to either. In addition to manual or animal labour, endless rope haulage has been employed, and in some cases small locomotives have been used. For large gasworks these early methods are altogether inadequate, and the mechanical equipment of such works cannot be regarded as complete without suitable hot coke conveyors and overhead bunkers for holding the coke ready for loading into trucks or carts.

Few of the earlier conveyor installations for the mechanical handling of coke are still in use, most of them having been scrapped after a comparatively short and chequered career. Manual methods are also fast disappearing owing to the inflated value labour puts upon its limited performances. The first hot coke conveyors of note were built about the year 1898, and were of the push-plate type, having a trough 27 in. in width, composed of cast-iron sections, and push-plates of malleable cast iron. The latter were attached, at 24 in. pitch, to a central chain, and were dragged along on a renewable wrought-iron bar, the wear on the chains being taken by iron blocks fixed to the links and capable of being replaced when necessary. The return strand of the conveyor was led over guide pulleys, either underneath the bench floor or high up out of the way of the retorts. The speed at which these conveyors ran was about 48 ft. per minute, and their capacity was about 20 tons per hour. They performed their work well, but their life was short, under the trying conditions to which they were subjected, and the expenditure on repairs and renewals of parts was very heavy. The chain, being central, suffered severely from the action of the hot coke, to which it was fully exposed. The first complete installation of this kind was erected at the Gaythorn Gasworks in 1898, to the design of the late Mr G. E. Stevenson; this plant was discarded in 1903 for the reasons above mentioned, and also on account of the excessive breakage of the coke.

The conditions to be aimed at in the design of a hot coke conveyor are: simplicity; small number of wearing parts; interchangeability of wearing surfaces and of worn and broken parts; protection of wearing and working parts from contact with the hot coke; and ability to keep the temperature of the conveyor itself as even as possible, in order to avoid distortion of its parts through sudden heating or cooling.

Most modern hot coke conveyors in use in gasworks are based more or less on the one fundamental principle, consisting of substantial iron troughs, 2 ft. to 2 ft. 6 in. in width, in which scrapers are manipulated by a chain, or more often by two chains, travelling at a speed of 30 ft. to 60 ft. per minute. When two chains are used, they are either concealed in suitable channels in the sides of the trough, or placed outside the trough altogether. Conveyors of the plate or tray type, although they tend to protect the chains from the coke, and cause less wear of the trough, do not appear to have been so

successful. In conveyors of this type the coke rests on the plates and moves with them, so that the plates become damaged by excessive heating, whilst the heat soon spreads to the chains, which must suffer considerably unless the trough in which the conveyor travels is filled with water up to the level of the plates.

An attempt to prevent breakage of the coke, and at the same time to reduce the wear of the trough, has been made by constructing the push-plates in such a form that they partly support the coke, thereby preventing, wholly or partially, its contact with the trough. This type of conveyor may be termed a combination of the push-plate and the travelling-plate conveyor, and to some extent it protects the coke from breakage, but, on the other hand, the "breeze" which is always present will find its way between the pushing agents and the trough, so that the protection afforded to the latter is more illusory than real.

The chains employed in hot coke conveyors are nearly all of the long-link type, but differ widely in details of construction. They may be either forged or of malleable cast iron, or of manganese cast steel. The advantages claimed for the latter material are that it contains fewer blow-holes than ordinary cast steel, and is more durable under the severe conditions to which such chains are frequently exposed. The ultimate tensile strength of the chains is very much greater with this material, but it is not advisable to reduce the sectional area of the links in proportion, especially as the elastic limit of the manganese steel is rather low; and although the material is suitable for general use on hot-coke conveyors, it should not be employed when directly exposed to the action of the hot coke.

Of the hot coke conveyors here described, the first four are of the tray or plate type, in which the coke is carried on plates, trays, gratings, etc.; the fifth, the West conveyor, is inter-

mediate between this type and the push-plate type, as in it the coke is partly carried and partly pushed along; and the remainder are of the push-plate type.

The New Conveyor Co.'s Hot Coke Conveyor.—This conveyor consists of a water-tight trough, through which pass closely-fitting tray plates attached to a single

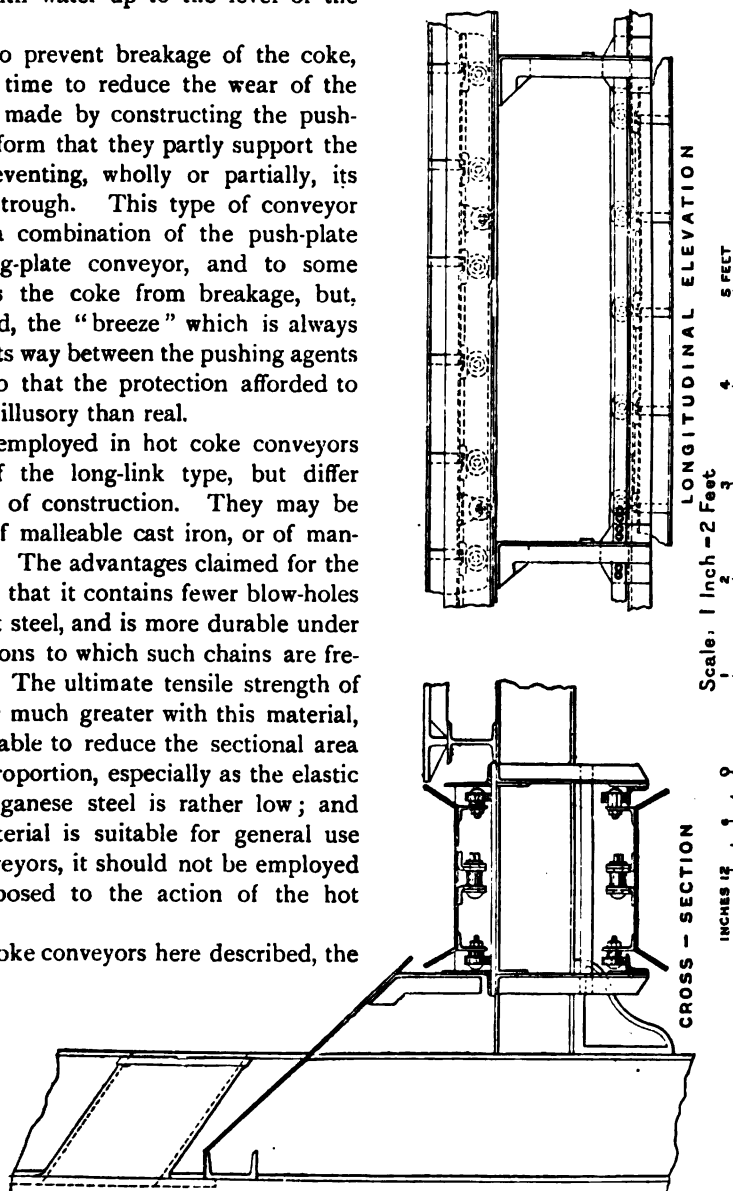


Fig. 201. New Conveyor Co.'s Hot Coke Conveyor.

chain. These plates are 1 ft. 6 in. to 2 ft. in width, and $13\frac{1}{2}$ in. in length; they are joggled downwards at one end to receive the flat front part of the succeeding plate, in order to prevent the "breeze" from penetrating beneath the carrying plate. The chain now used is constructed entirely of steel, having steel bushes secured to the inner links and steel pins to the outer links. Small rollers are attached by means of angle-brackets to the under side of the conveyor plate, to carry the plates and chain, and, as they run in water, oiling is dispensed with. The chain has a breaking strength of 29 tons. The brackets which carry the rollers are made of manganese steel, either as shown in Fig. 201, or in one piece with a spindle or pin. The rollers are $2\frac{3}{4}$ in. in diameter, and are also of manganese steel. The framework which carries the whole conveyor is built of angle-bars. To prevent side play of the return strand, rubbing strips are fitted above the lower angle-bars of the conveyor. The speed of travel of these conveyors is about 45 ft. per minute, and the capacity when handling coke from 20-ft. retorts is about 30 tons per hour.

Marshall's Hot Coke Conveyor.—This conveyor was designed by Mr F. D. Marshall, of the Copenhagen Gasworks. It consists of a water-tight wrought-iron trough, fitted on either side with a series of guide rollers, upon which the two conveyor chains run. Both guide wheels and chains are amply protected by sheet-iron coverings. The chains consist of wrought-iron links, and attached to each alternate link are metal cradles which form the connection between the two chains, and which carry the coke. The bottoms of these cradles are formed by a series of iron bars, which may be either round bars, as shown at A, or flat bars, as shown at B (Fig. 202). The conveyor trough is kept partially filled with water, so that the lower portion of the cradle is always well submerged. In this conveyor the cradles, whether constructed of flat or round bars, are not likely to be distorted by heat, even should the water supply run short, and any extension or contraction of the bars due to varying temperature cannot affect the pitch of the chain. The conveyor is driven in the usual manner by hexagonal terminals, and the coke is discharged as the cradles pass round the delivery terminal. One drawback to this conveyor is the accumulation of breeze in the trough, but the provision of means for removing this should not be a difficult matter.

Bronder's Hot Coke Conveyor.—This conveyor, Fig. 203, designed by Mr G. A. Bronder, of New York, somewhat resembles the gravity bucket conveyor. It runs in a water-tight trough filled with water to a certain level, the water being slowly circulated by mechanism resembling a water wheel. The chain of buckets runs in the trough, the sides of which form the rails for the supporting rollers. The whole conveyor is covered in along its entire length, and the lower edge of the cover dips into the water in the trough, making an air-tight joint. The flue thus formed is connected at each bench with a number of shoots, through which the coke drops into the conveyor buckets; when not in use these shoots are covered. At the ends of the trough and flue, a large pipe leads to an exhauster, which draws away the steam and vapour created by the quenching process, and sends it to a chimney which carries it off above the roof of the retort house. The conveyor buckets are connected by brackets of horse-shoe shape, which extend upwards beyond the sides of the buckets and are connected with the links of the driving chains. When the conveyor is at work, the covers of the mouthpieces are opened and the coke is discharged into the buckets; at the same time the water valves are opened, thereby quenching the charges and spraying them as they pass beneath the water outlets. Scrapers are provided to collect and deliver into a collecting chamber at one end any "breeze" which may have escaped the buckets. The propeller wheel already referred to takes the water from this collecting chamber and forces it again to the other end of the trough.

West's Hot Coke Conveyor.—This conveyor consists of a substantial trough in which one wide chain travels, partly carrying and partly dragging the coke. The original

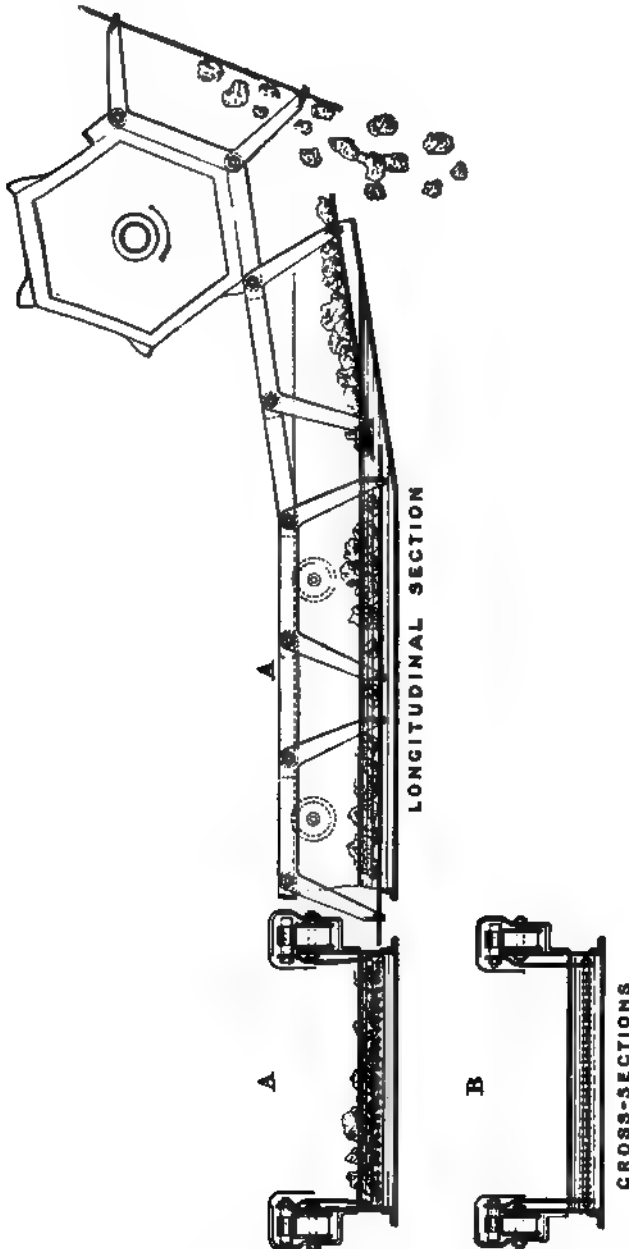


Fig. 202. Marshall's Hot Coke Conveyor.

of this type of conveyor was introduced many years ago, and it was probably the first conveyor for this purpose. The illustration (Fig. 204) shows the present form, which consists of an outer iron steel trough with hard cast-iron internal trough lining and

renewable side pieces. The bottom plates are loosely fixed and kept in position by means of the angle-bars on which the chain drags. The chain has a pitch of 12 in., and the pins in the hinged joints are $1\frac{9}{16}$ in. in diameter by 8 in. in length in the bearing. Each link consists of a cast block, with eyes at each end for the joint pins, and provided with an arm on each side extending to the sides of the trough, the ends of these arms sliding on the angle-bars fixed at the corners of the trough. The links are connected together by two steel side links and hinge pins. These side links have slotted ends, so that they can be passed over the head of the pin when the side links are at right angles with the chain blocks. When in line with the blocks the projections at the sides of the blocks prevent the side links from becoming disengaged from the pins. The wear of the chain on the trough is minimised by hard cast-iron shoes fitted thereto. There being only one chain, only one sprocket wheel is required at each terminal; this is made with teeth $6\frac{1}{2}$ in. in width. The chain described is designed for conveyors 500 ft. in length,

running at a speed of about 40 ft. per minute. During the use of the conveyor, quenching water is run into the trough as is usual with all hot coke conveyors.

Wild's Hot Coke Conveyor.

This conveyor consists of a substantial trough, 2 ft. to 2 ft. 6 in. in width by 9 in. in depth, which may be either of cast iron or of steel. In Fig. 205 it is shown supported by cast-iron brackets, to which are secured the rails

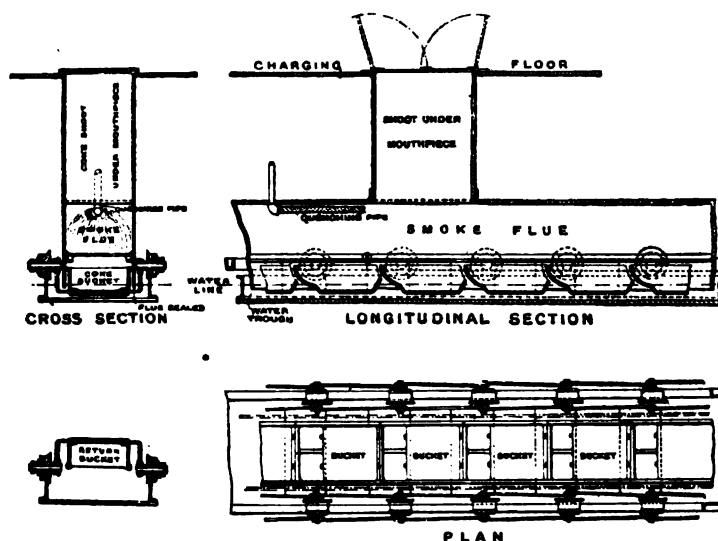


Fig. 203. Bronder's Hot Coke Conveyor.

for supporting the two strands of the chains; the return strand of the chain is shown beneath the trough, both chains being outside the trough and secured on either side to the push-plates, so that only the scraper comes in contact with the hot coke. The chains are usually composed of ordinary welded links of 12 in. pitch. They are, however, sometimes made of manganese steel. Every second link carries a push-plate, so that these plates are 24 in. apart. The push-plates are connected by means of arms to the axles, which carry 6-in. flanged rollers, $1\frac{1}{2}$ in. in width on the face. The advantage of this type of conveyor is that all the moving parts, viz., chains, rollers, etc., run outside the trough and that only the push-plates come in contact with the hot coke.

This method of construction allows for lubrication of the pins and rollers, thus minimising to a considerable extent the inevitable wear and tear inseparable from this type of conveyor.

The De Brouwer Hot Coke Conveyor.—This appliance was originally invented and patented by M. De Brouwer, an eminent engineer of Bruges, from whose initials this conveyor derives the trade mark "D.B." The sole rights for its manufacture

in this country were acquired some few years ago, by Messrs W. J. Jenkins & Co., Ltd., of Retford, Notts. Since then the author has gathered that between sixty and seventy

Fig. 204. West's Hot Coke Conveyor.

miles of this chain and over eight miles of fully equipped conveying plants have been installed in this country alone.

The conveyor consists of an open rectangular wrought-iron trough of substantial construction, 1 ft. 8 in. to 3 ft. in width, and 3 to 6 in. in depth, extending along the entire front of the retort settings. This trough is fitted with renewable cast-iron bottom plates with raised strips along each side, forming continuous ledges along which run two strands of chain, joined at intervals of about 2 ft. by flat cross-bars.

The chain consists of block-links, alternating with double side links, the bosses of which work in holes in the blocks, and are held together by steel rivets. The blocks being deeper than the links, take all wear caused by running along the track. As will be noticed by a close scrutiny of the above detail all holes are drilled out

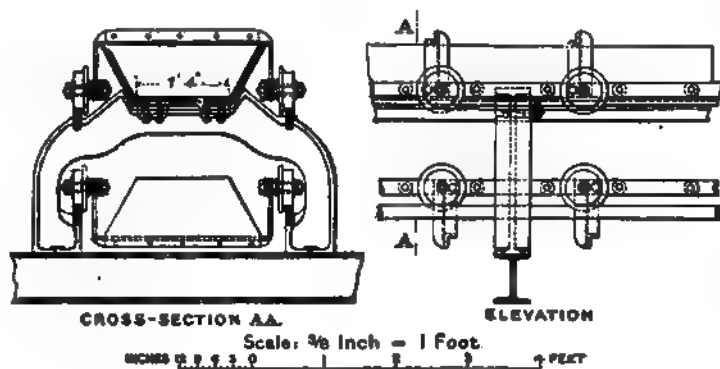


Fig. 205. Wild's Hot Coke Conveyor.

of centre so as to offer greater wearing thicknesses in direction of pull. The chains are protected from coke falling into them by cover angles or tees bolted to the sides of the trough, as shown in the illustration. The return strand of the chain is usually carried on

Fig. 206. Cross Section of Trough with renewable holding-down Tees partially removed to show Method of Chains Construction.

a path formed of steel angles, with cast-iron renewable wearing strips bolted on. This may be arranged under the floor as shown in Fig. 206, or carried on brackets overhead. As will be seen from the cross section, every part of the trough may be easily and rapidly

Fig. 207. Method of Assembling Block and Side Links.

renewed. These conveyors are usually arranged horizontally in front of the retort bench, as shown in Fig. 208, but work equally well up to an angle of 35° , or if extra deep cross-bars are used, up to 40° . Before the hot coke is fed in, the trough is filled with water to a certain depth throughout its length. The coke, as soon as it is drawn along by the conveyor bars, which act as push-plates, sweeps the water before it along the trough. This action continues for some distance up the slope at the delivery end, the water thence

flowing back like a miniature cataract on the partially quenched coke, thoroughly quenching it and completing the quenching process. As the red-hot coke leaves the retort it is directed into the trough by a deflecting plate or shoot, and is drawn forward by the cross-bars.

Fig. 208. Coke Plant at Salford.

Fig. 209. Birmingham Coke Plant.

The coke can also be quenched by sprays of water arranged at intervals along the trough, or where part is arranged on the incline, automatic sprays are provided, as shown at A (Fig. 209). This part of the conveyor is completely closed in, so that the coke may be kept in contact with the steam for as long a time as possible to ensure its being thoroughly quenched. This arrangement has incidentally the advantage of keeping the

steam away from the retort house, the covered in portion acting as a chimney and drawing the steam to the upper end as shown below.

The illustration, Fig. 209, shows four inclined D.B. Hot Coke Conveyors as they leave the retort house, and serve to show the angle at which some of them can be employed. The conveyors are shown delivering into hoppers with screening plants underneath for extracting the small coke and "breeze" and delivering the large coke into wagons.



Fig. 210. Cross Section of Trough and Chain of Early Form.

Modifications, Etc.—The late Mr E. Merz, formerly engineer of the Cassel Gasworks, introduced some modifications in the construction of this conveyor; the bottom and sides of the trough are made double, with a lining (Fig. 210), so that if desired, the interior of the troughing can readily be renewed, the changing plates being fastened by bolts. If considerations of space should render it convenient to have the return strand of the chain carried under the conveyor trough, this can be effected without making the conveyor more than 8 in. in depth throughout. The inclined ends of this conveyor, and also the shoot which receives the coke and a portion of the uptake which leads away the fumes, are shown in Fig. 211. In the plan is shown the support for the terminals, one with the chain on, and the other with the chain removed. Another modification of the De Brouwer conveyor is that of Mr F. D. Marshall, of Copenhagen. The object of the device is to equalise the flow of water by providing a sort of sluice for withdrawing the excess of

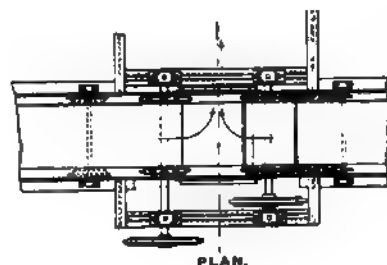


Fig. 211. Merz Modification of De Brouwer Conveyor.

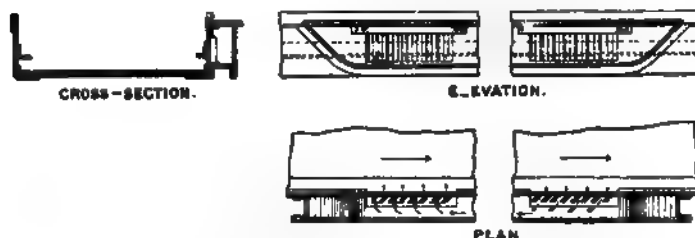


Fig. 212. Marshall's Modification of De Brouwer Conveyor.

water at any point in the trough. This arrangement is shown in Fig. 212. The channels by which the water is drawn off are fitted with lids, in order to facilitate cleaning. The chief merit of this arrangement appears to lie in preventing the water from flooding that section of the trough which abuts on the inclined plane, as at that point the accumulation of water is sometimes so great that it overflows the trough.

Merz Hot Coke Conveyor.—This conveyor owes its origin to a desire to

improve one of the first De Brouwer conveyors which was erected at the Cassel Gasworks, and which gave considerable trouble owing to its very light construction. The late Mr E. Merz contended that the round or octagonal bars of the De Brouwer conveyor had not sufficient hold on the coke, which was liable to slip back over or under the bar; and also that with the short links in vogue at the time it was impossible to obtain chains of absolutely even lengths. He therefore designed the conveyor shown in Fig. 213. Instead of the chains running in the bottom of the trough, they are concealed in a suitable groove at the top, and the bars connecting the chains are replaced by cast-iron rakes, which are supported by rollers. The prongs of the rakes being set at an angle, the conveyor trough is relieved of a portion of the weight of the coke, thus reducing the work, and also the wear of the trough. The conveyor is built in two different patterns, viz., with the supporting rollers on the ends of the rakes, or with the supporting rollers fixed to the trough so that

the chain travels over the rollers. The former construction is illustrated in Fig. 213, and the latter in Fig. 214, which also shows the general arrangement of the conveyor. The trough is made of cast iron, and consists of sections of about 4 ft. 8 in. in length, joined together by flanges.

The Merz conveyor

at the Cassel Gasworks is 190 ft. in length, travels at the rate of about 30 ft. per minute, and when in full work consumes about 5 H.P.; it has been at work for about sixteen years, and so far has given very little trouble. Fig. 215 gives a photographic view of this conveyor.

Dempster's Hot Coke Conveyor.—This conveyor, designed by Messrs R. Dempster & Sons, Ltd., of Elland, Yorkshire, and illustrated in Fig. 216, is so constructed as to keep the chains, rollers, and bearings out of reach of the hot coke and of the quenching water. The trough is built of plates and angle-bars, with renewable cast-iron liner plates at the bottom, which are prevented from shifting by flat steel strips bolted on the inside of the angle-bars; the cast-iron plates are thus free to expand and contract along the trough. On the outside of the trough, at about 3 ft. pitch, are bolted small iron brackets carrying turned steel spindles; working on these spindles are flanged cast-iron rollers which support and guide the chains. The chains used are composed of interchangeable malleable cast-iron links, with parallel sides, connected together by square-headed hardened steel pins which do not project at the sides. The rollers being attached to the trough instead of to the chain, the weight of the chain is diminished whilst the rollers and lubricators are easy of access even when the conveyor is running. The rakes or scrapers are of cast steel, and are designed to minimise the breakage of the coke by reducing the tendency to crush it between the scraper and the trough. In order still further to prolong the life of the chains, the terminals are fitted

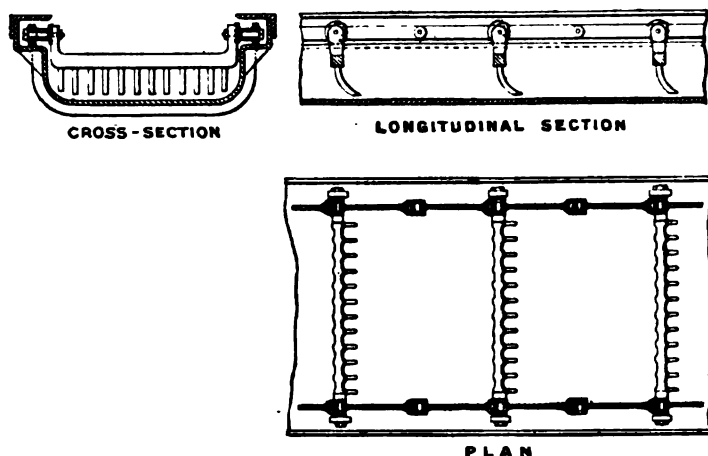


Fig. 213. Merz Hot Coke Conveyor.

with the Toogood equalising gear, to be described (Chapter XVI.). This conveyor may also be worked on an incline of say 30° to 40° , thus acting also as an elevator. Such a conveyor, having a trough 2 ft. in width, and rakes at 3 ft. pitch, travelling at 35 ft. per minute, would easily deal with the coke from ten beds of 20 ft. inclined retorts, provided the conveyor were made with a run of about 50 ft. outside the retort house, or from the last bed of retorts.

In all conveyors of the push-plate type it is essential to lead the delivery end up an incline; this is generally done for convenience in delivery, but its principal use is in completing the quenching of the coke. As soon as the ascent is materially mented b of the ir coke by r portion o uptake or or vapour that at th still hot sufficientl important automatic the hot c

Fig. 214. General Arrangement of the Merz Hot Coke Conveyor.

recently engaged the attention of several manufacturers, and this is an important improvement in large installations, where the whole contents of a 20-ft. retort are deposited on to the conveyor over a space of only 5 or 6 ft. of its length, the conveyor being then practically empty for some yards.

Intermittent Coke Handling

A considerable amount of destruction is unavoidable on all conveyors of the continuous chain type mentioned in the foregoing when coming in contact with the coke. This is the more so the smaller the pitch of the conveyor chain, and therefore the larger

the number of joints. This destructive action can be diminished and localised by the employment of an intermittent handling device in which the whole contents of one retort can be conveyed in one large receptacle, without mechanical parts, and which is easily and cheaply repaired or renewed, whilst the rest of the mechanism does not come in contact at all with the destructive coke; whereas a continuous conveyor of the chain type is exposed to injury in practically all its parts and for its whole length.

Fig. 215. Photographic View of Merz Hot Coke Conveyor at Cassel Gasworks.

There are, however, many instances, particularly in older retort houses, where continuous mechanical coke conveyors are preferable, even with their drawbacks, owing to the lack of headroom necessary for telfers, and for other reasons.

Hitherto the telfer has been the only intermittent device for such purposes, and since this subject is dealt with in Chapter XXVII., it will only be necessary to state here that the telfer machine for this purpose is provided with a second motor and winding gear from which a basket-like steel skip or cradle is lowered in front of the retort to be drawn; the coke is then received, the cradle raised, and the telfer travels out of the retort



Fig. 216. Dempster's Hot Coke Conveyor.

house. Just outside is a tank filled with water, into which the cradle with its contents is dipped by lowering it by the winding gear for the second time; the quenched coke is then raised again and conveyed on to the coke heap. The telfer can then either return by the same way for the next load, or what is better, it can travel always in the same direction if a closed and endless track is provided.

The "Ideal" Coke System of disposal from the retort house is the introduction of Messrs Drakes, Ltd., of Halifax. It promises well to overcome the majority of the difficulties contingent to the handling of hot gas coke.

In the following description an account is given of the first installation on this principle set to work in December 1916 at the Bradford Road Gasworks of the Manchester Corporation.¹ The installation is represented in Figs. 217 to 221. Fig. 217 shows the retort benches, the rail-track with the coke-discharging machine, and the numerous openings in the wall through which the coke is conveyed on to the quenching bench or hearth outside the retort house.

The machine proper is illustrated in Figs. 218 to 221, the last-named view being a cross section to a larger scale, through the retort house and quenching bench.

A photographic view (Fig. 222) shows the skip in the middle position, just before beginning to tip. The appliance is mounted on a bogie running on rails in front of the retort bench, and is similar to a skip hoist used for boiler-house refuse, but with a lesser gradient. The coke is delivered by a steel-cased multiple shoot into the skip from the various tiers of retorts; this shoot is attached to the travelling carriage of the machine by a steel channel frame, and has ample bracing to secure rigidity. The vanes of the shoot are arranged to project slightly beyond the cast-iron mouthpiece of the retorts, so that the whole of the coke passes into the skip without any spilling. The shoot is almost entirely enclosed, thus shielding the operator from the intense heat. A retort of a higher tier does not mean a greater fall for the coke, as thus the skip is raised further above the incline to receive its load.

In working, the skip is set at such a position at the bottom of the shoot that the coke is received with a minimum fall, obviating the formation of breeze.

This skip travels on four wheels on double tracks, and the divergence of the lower one, on which the forward wheels travel, causes it, when it reaches the top, to slowly tilt, so that the coke is discharged gently into the fixed shoot in the retort house wall prepared to receive it, and down which the coke slides on to the quenching bench outside the retort house, where it is spread in an even layer and quenched with a minimum of trouble.

The skip cradle is raised on its inclined path by means of two steel-wire ropes, one at each side, which are each tested to 6 tons, and which run round two large guide pulleys at the top. The track is constructed of steel channels and angles, and has attached to the underside a steel plate, guard, or shoot, which prevents any coke which may be accidentally spilled from the skip in tipping from falling on to the men when passing round the machine. The guide pulleys and hoisting drums are of ample size in order to reduce the wear and tear on the wire ropes, due to constant bending. The hoisting drums are of cast iron, made in two sections, each having an inner barrel and an outer grooved sleeve, and so arranged that the sleeve may be adjusted to any desired position in order to keep an equal tension on both hoisting ropes, and also to take up any inequality in their lengths. The four runner wheels on the skip, and the guide pulleys for the ropes, are mounted on roller bearings in order to eliminate friction.

There are two electro-motors, one for travelling and one for hoisting, both of which

¹ From an article by the same Author, which appeared in *Engineering*, 4th Oct. 1918.

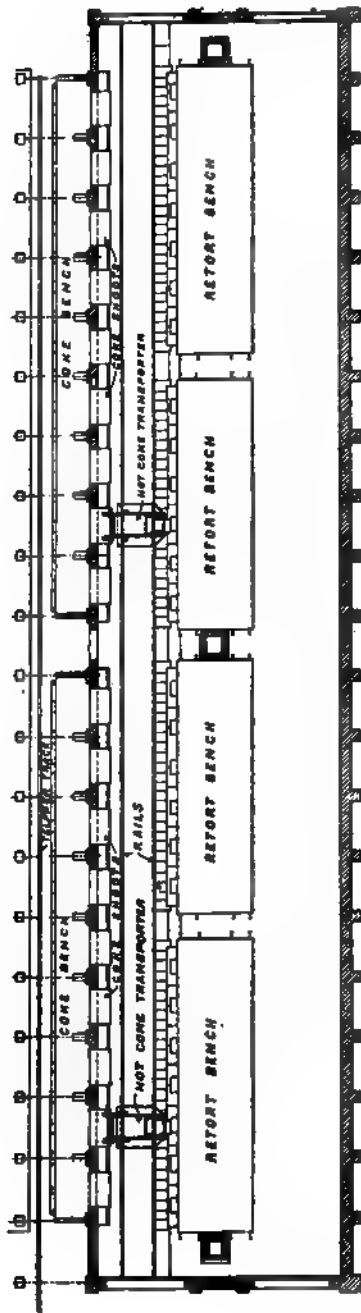


Fig. 217. General Ground Plan of the Retort House of the Bradford Road Gasworks, Manchester.

PLAN

Figs. 218, 219, and 220. Three Views of the "Ideal" Coke-Handling Machine, at the Bradford Road Gasworks, Manchester.

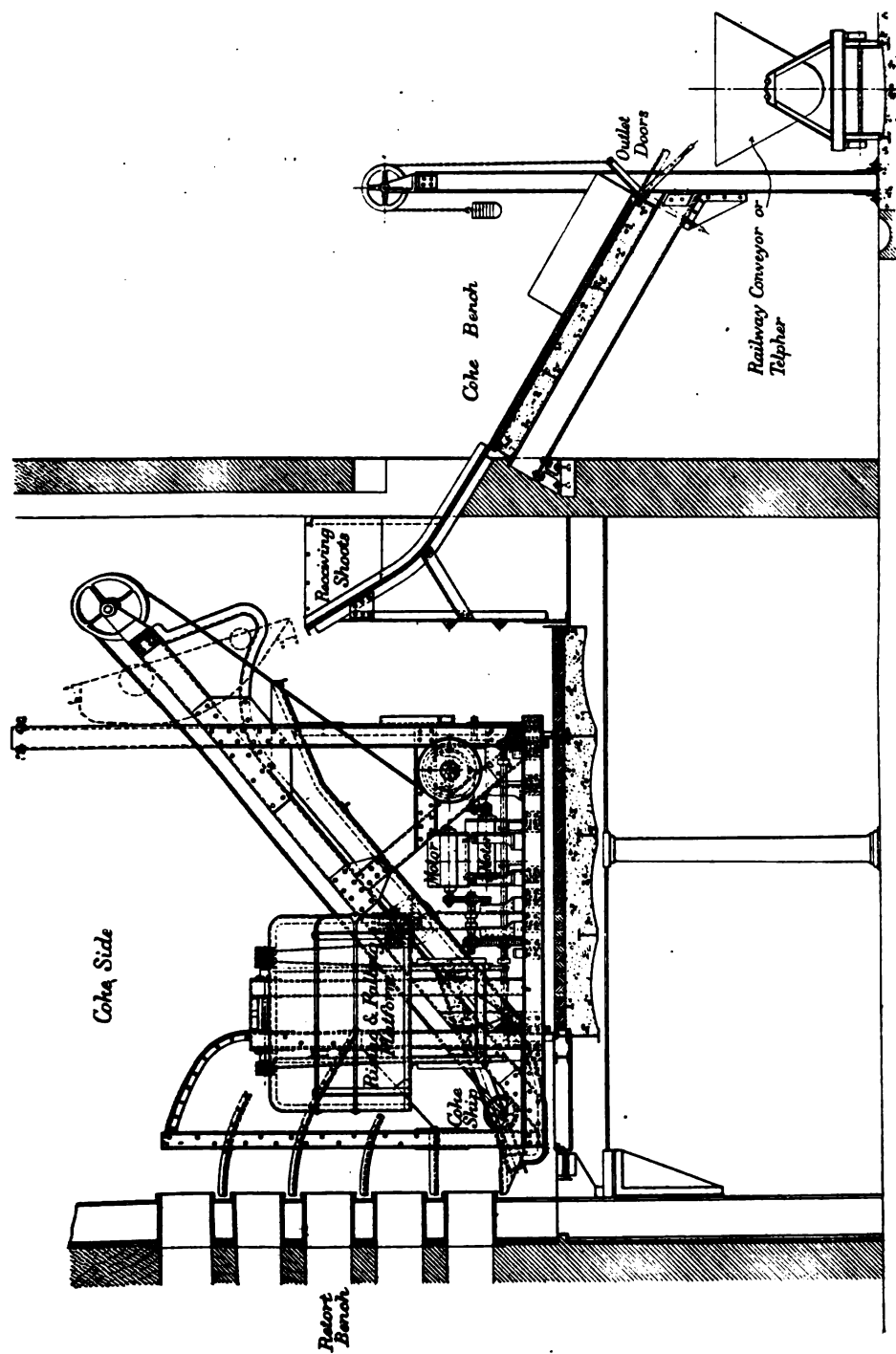


Fig. 221. Cross Section through Retort House and Coke Bench, showing the "Ideal" Coke Handling Machine.

operations can be carried on simultaneously; a skip load need not therefore necessarily be dumped on the nearest part of the hearth. These motors are of the totally enclosed dustproof type.

The travelling carriage of the machine is a strong framework of steel channels, to which the hoisting and travelling motors are secured. The travelling wheels are of cast steel, and have machine-cut spur rims bolted thereto, the power being transmitted from the travelling motor through a train of mild-steel machine-cut gear wheels.

An adjustable platform is provided for the attendant who opens and closes the mouthpiece lids on the retorts of the upper tiers; this platform is counterbalanced, and can be operated with ease by means of a hand wheel, from the driver's platform. A steel-plate shield is fixed to the "lidman's" platform, to prevent his suffering any discomfort from the heat of the coke, and an automatic safety device comes into operation should either of the steel-hoisting ropes break.

The coke skip in this installation is 7 ft. long and 5 ft. wide, and of a capacity to receive the contents of one retort (24 in. by 18 in. by 22 ft.). It is constructed of steel plates and angles riveted together, and is mounted on a separate cradle or carriage, being easily removable when necessary. It may be interesting to note that whereas, on the installation of the plant, the manager, Mr Hill, was prepared to renew the skips every fortnight if need be, so long as the system handled his coke expeditiously, yet the original skip fixed in December 1916 was continuously at work without any need of repair until April 1920, when it was replaced by a new one. The skip cradle is constructed of steel channels, to which are fixed forged-steel trunnions for the runner wheels, which are of cast steel and fitted with roller bearings as well as the guide pulleys, which revolve on steel pins fixed in the brackets at the top of the track frame. The hoisting gear consists of two drums or barrels, one on each side of the machine, keyed on to a common shaft, which is driven through worm gearing by a totally enclosed reversible crane motor. In addition to the worm gearing, there is an automatic solenoid brake, and by stopping the motor the skip may be instantly brought to rest at any point on the track, as, for instance, when it is desired to set the skip in position for receiving the coke from the upper tiers of retorts. At the upper and lower ends of the track there is, moreover, an automatic cut-out switch, which renders over-winding impossible. In actual working the skip is automatically stopped on the hoisting motion, the attendants using the controller to stop it on the lowering motion only, when dealing with the upper tiers of retorts. Two controllers of the tramcar type are employed, one for the hoisting and one for the travelling motion, and it is possible for the operator to both travel and hoist at the same time. The electric current, which in this case is 400 volts D.C., is taken from overhead cables.

One important feature of this system is that by utilising a coke-quenching bench outside the house, instead of delivering into telfer skips, conveyors, etc., the operations inside the retort house are not dependent upon the removal of the coke to the storage plant; it can, in fact, be quenched and remain there as long as desired, provided it is taken away before the next round of retorts is due, and if there is not sufficient room for the second round to be discharged on the bench while the first round remains. Even should there be a glut of coke at any one point on the coke bench, delivery can be effected with this machine at any other point. It is, however, far better to clear the coke from the hearth as it is made, and there is plenty of time for doing this in between the rounds. It will be seen that where the ordinary coke is desired without screening, it can be delivered direct from the quenching bench into carts, thus avoiding handling in other directions.

The actual time taken in discharging a 24-in. by 18-in. retort, 22 ft. long, and depositing the coke on the quenching bench, is thirty-five seconds, and the skip is again

Fig. 222. Photographic View of the "Ideal" Coke Handling Machine,
at the Bradford Road Gasworks, Manchester.

in position to take the next retort in a further ten seconds, the whole cycle of operations being performed in forty-five seconds. The coke is thus transported in a bee-line from the retort, and at right angles to the setting, to the outside of the house, the distance travelled by each charge being reduced to a minimum.

Two operators are required per shift, one for driving the machine and the other for attending to the mouthpiece lids; in a small works it would be quite possible for one operator to attend to both. With this system there is no spilling of the coke, and the retort house is always clean and tidy, and the atmosphere is as clear as it can possibly be in a retort house.

By the courtesy of Mr J. R. Hill, the manager of the Bradford Road Gasworks of the Manchester Corporation, the Author is able to give an approximate idea of the economy effected by the use of this coke-handling system at the works under his control, although he has not yet been able to go fully into the cost of handling. The following figures will give some idea:—200 tons of coal are carbonised per day, and the saleable coke is estimated at 10 cwt. per ton of coal; this machine handles 100 tons per day. One man is employed per shift at 10s., or £1 for the two shifts per day. The expense of getting the coke out of the retort house is, for manual labour, not including driving power, repairs, and capital expense, 2s. 4d. per ton. The consumption of current is 160 units per day of twenty-four hours. It is estimated that the coal handling and breaking plant consumes 75 per cent., or 120 units of this. The Fiddes-Aldridge stoking machine takes approximately 30 units, leaving, it is estimated, about 10 units for the hot coke conveying; this is an exceedingly low consumption.

CHAPTER XIII

COAL FACE CONVEYORS

MECHANICAL appliances for removing coal and other minerals from the working face are very old, and some crude devices were used, it is believed, even by the ancient Egyptians. The last decade witnessed great activity in this direction in consequence of the thick coal seams becoming exhausted, and thin seams can only be economically worked by coal-cutters and coal face conveyors in one form or another. The advent of the mechanical coal-cutter in connection with the long wall coal face makes the face conveyor not only more applicable to coal getting, but almost indispensable. The reduction in the hours of labour has further emphasised the importance of mechanical appliances for economical working under ground. Space does not permit of going fully into this vast subject—sufficient to fill a large volume by itself¹—so it is only proposed to give a general idea of the different systems without entering into the application of the machine in the mines, as this would be beyond the scope of this book. There is also a great similarity between some of the appliances. The most important are mentioned, and references are given for those who wish to be informed as to where fuller descriptions are to be found. The oldest methods were probably a kind of sledge, which was dragged along the working face to the loading point by ropes and blocks, or a skip travelling on a rope, which was stretched along the roof of the seam, and on which the skip was pushed along by hand and tipped into the tub in the gate. This was used in the eighties. Isolated appliances, the outcome of the inventive genius of the coal getters or the engineer, have enjoyed only a local popularity, and none of these have become established as economical labour-aiding appliances. A detailed description of the manual conveyors would have only historical value; suffice it to say that they consisted of a small tram or a long low receptacle with a capacity of a few hundred-weights, which were applied in some thin seams with varied success. As the capacity is very limited, this method is only applicable in seams where the absence of suitable driving power or some other circumstance preclude power-driven devices.

The systems now in use may be divided into four classes:—

- A.—Appliances in which the Coal is Carried in a Receptacle.**
- B.—Appliances in which the Coal is Carried on an Endless Band.**
- C.—Appliances in which the Coal is Dragged along in a Fixed Trough by a Chain or Scrapers.**
- D.—Appliances which Propel the Material either by a Simple Reciprocating Motion down an Inclined Trough, or by a more Complex Motion on the Level, and even Slightly Uphill.**

Class A.—Appliances in which the Coal is Carried in a Receptacle.—Appliances under this head generally involve small capital expenditure, and consist of

¹ A volume of over 300 pages, with 274 illustrations and 5 plates, has been written exclusively on this subject by Arthur Gerke, of Bochum, 1913, entitled "Ueber Abbauförderung."

one or more small coal tubs upon rails running in front of the coal face. At the gateway a bridge is formed and a full-sized tub placed underneath, which receives the contents of the smaller tub or tubs through an outlet controlled by a slide. The small tub is made with sloping sides and mounted upon axles, which allow the bottom of the tub to approach close to the rail level, and one of the sides near the coal face is lower to facilitate filling. In this class are included the Mickley¹ and the Bothwell² conveyors, which consist of low trucks which are pulled along in front of the coal face. With the latter type of trucks, trains are formed consisting of as many as twenty-four trucks. The Gibb³ conveyor (see Fig. 223) consists of eight or nine segments, each of which is supported by four cast-steel wheels. The first and last segments have closed ends, so that the whole is like one receptacle. Such a conveyor is in use at the Muiravonside Colliery in Linlithgowshire. It consists of nine segments with a total length of 56 ft.,

Fig. 223. Gibb Coal Face Conveyor.

16 in. wide and 8 in. deep at the side of the coal face, and 14 in. deep at the other side; this conveyor holds $2\frac{1}{2}$ tons of coal.

Similar appliances of the same class are the Bunker conveyor,⁴ and the Cummings & Gardiner,⁵ Walton & Rayner,⁶ and Thomson conveyors.⁷ All these pass backward and forward along the coal face to the gateway where they deposit their load into ordinary mine tubs, and sometimes they pass beyond the gate to the coal face on the other side, alternately taking the coal from the face on either side of the gate.

All these appliances run on rails of ordinary section except the Bothwell, which runs

¹ Mickley. This is more fully described in the *Transactions of the North of England Institute*, vol. lv., page 176.

² Bothwell. This is described in *The Colliery Guardian*, II., 1909, page 622.

³ Gibb. This is fully described in *The Colliery Guardian*, II., 1909, page 59.

⁴ This is described in *The Colliery Guardian*, II., 1911, page 1286, and *The Transactions of the Institute of Mining Engineers*, 1912, page 391, also in "The Coal Age," 1912, page 643.

⁵ Cummings & Gardiner, *Colliery Guardian*, II., 1911, page 167.

⁶ Walton & Rayner. Described in *Colliery Guardian*, I., 1911, page 1228.

⁷ Thomson. Described in *Iron and Coal Trade Review*, 1909, Nov. 26, and "Coal Age," 1912, page 645.

on a U-shaped channel, and the Thomson, which is not supported by wheels, but slides in U-shaped channels. The drive is by steel rope which passes over rollers at the terminals, manipulated by hand or pneumatic gear. The unloading is effected in various ways. The Mickley and Bunker conveyors deliver through openings controlled by slides; the Bothwell has an automatic tipping device by which each segment delivers its load by tipping up by gravity, and assuming its former position as soon as empty. Walton & Rayner employ a textile band which rests with its upper strand in the bottom of the segments, which are set in motion when the train is in the unloading position at the gateway. Cummings & Gardiner, as well as Gibb, use a steel band employed in a similar manner. Thomson's conveyor (Fig. 224), which is essentially a trough open

Fig. 224. The Thomson Coal Face Conveyor. View from Coal Face.

on one side, is emptied by an oblique scraper as it passes over the bridge at the gate.

As regards capacity, the Mickley conveyor at the Prudhoe Pit of the Mickley Coal Company handles 5 tons per hour. The installation of the Cummings & Gardiner conveyor at Hampstead Colliery has increased the output from 2·7 tons to 4·5 tons per man per shift. The Bothwell conveyor of the Bothwell Park Colliery has increased the output from 3 tons to 6·5 tons per man per shift. The Gibb conveyor at the Muiravonside Colliery has a capacity of 13 tons per hour.

Class B.—Appliances in which the Coal is Carried on an Endless Movable Band.—As band conveyors are fully dealt with in Chapter VII., it will only be necessary to mention any modifications, for the specific use, of this well-known type of conveyor (introduced by Richard Sutcliffe, of Wakefield). For the band itself hemp or flax is most serviceable. Jute, cotton, and the bass of the ancient lime tree are also

used, but they do not last as long, and occasionally woven wire bands are employed. All textile bands suffer much from the damp atmosphere in the mines, and to avoid this they are impregnated with various substances such as balata, tar being also used for this purpose.

According to Jenkins, the belt which has stood the best of all is about $\frac{5}{8}$ in. thick by 20 in. wide, and is made of best woven cotton treated with a special preservative compound, which penetrates the whole belt to prevent rot setting in, and keeps the belt in a flexible condition.

The width of the band generally varies between 20 and 24 in. The idlers with their frames are kept as low as possible, so that the conveyor may be applicable in small seams. Where troughing idlers are used they are, for the same reason, in a more shallow position

Fig. 225. Blackett Conveyor Delivering Coal into Main Gateway.

than is the usual practice. As regards inclines, up-gradients of 5 per cent. and downward gradients of 12° are within working limits.

The advantages of these belt conveyors are their suitability for an uneven floor, as the band can accommodate itself to the bends in the floor and roof. For instance, in cases where there is top ripping, *i.e.*, the rock above the coal is removed—the front or delivery end of the conveyor has to be elevated to deliver into the tubs. This can be done by putting the head on a special frame, or, if only a small amount is required, by putting wood packing underneath. The conveyor head is then fixed either by wedging props against the frame, or preferably by attaching chains to the framing and carrying them across the gate to a prop fixed for the purpose. The power for driving these conveyors is considerably less than for other appliances, and the working is both noiseless and dustless, which is of great importance. The disadvantages are the great wear and tear caused not only, as already mentioned, by the atmosphere, but as these conveyors, in common with all other coal face conveyors, have to be removed and re-erected constantly nearer the receding face, the re-erection does not always get the care

necessary to ensure all idlers being at right angles to the band and parallel with each other, and in consequence the band travels with a snake-like side motion, whereby the edges are injured and frayed by contact with stationary objects. The loading is not so easy as with other appliances, and an occasional dropping off of pieces of coal is also complained of; and finally, for wet mines they are quite unsuitable. Belt conveyors are mostly electrically driven, but where compressed air drive is necessary, an 8 to 12 H.P. air turbine, running at 1,200 revs. per minute, is fitted. Such turbines consist of two helical gears in a housing on which the compressed air impinges, and are coupled direct to the worm shaft, a simple change gear being added for reversing purposes to enable timber and packing materials to be sent up the face when required.

Fig. 226. The Allardice Coal Face Conveyor.

Class C.—Appliances in which the Coal is Dragged Along in a Stationary Trough by a Chain or Scrapers.¹—The best known and oldest conveyor of this type is that of Blackett² (Fig. 225). These machines are to all intents and purposes scraper conveyors (which have already been fully dealt with in Chapter V.), the principal feature being that they are built as low and compact as possible in order to leave sufficient head room for the coal to be put in and conveyed even in thin seams. The chain scrapers are now of the form of very large Ewart or Lee type of chain. Other scraper conveyors are by Greaves,³ Vinton,⁴ Ritchie & Sutcliffe.⁵ In order to

¹ Fully described in *Electrician*, vol. lxxxiii., 1919, page 666.

² Fully described in *The Colliery Guardian*, I., 1905, page 590.

³ Fully described in *The Colliery Guardian*, II., 1906, page 7.

⁴ Fully described in "Mines and Minerals," 1907, page 200.

⁵ Fully described in "The Coal Age," 1912, page 644.

reduce still further the height of the conveyor, Greaves leads the return strand of the chain back to the head end in a separate compartment in a very ingenious way, so that only a minimum of space is required.

The Allardice Coal Face Conveyor, Fig. 226, consists of an endless chain with trough, extending the full length of the face, sliding over the floor, and manipulated by a haulage gear. The return of the chain is overhead, being supported about every 9 ft. A suitable tension gear is provided at the top end of the face.

The chain consists of links made from flat bar, 9 in. pitch, with suitable scrapers arranged every 3 ft., which pass over sprocket wheels at each end of the face. The sprocket wheels are driven by the haulage gear through treble reduction machine-cut gearing placed in the main road, which is made wide enough for a double road. The chain for the haulage gear passes over this road, and the coal is delivered into tubs without any special devices. The main road is driven 15 to 20 ft. ahead of the coal face to allow of empty tubs being brought forward, so that no delay takes place in filling.

In some coal face conveyors, including that of Ritchie & Sutcliffe, textile bands are used as scrapers, and are supported by rollers or slide on the bottom of the trough.

Class D.—Appliances which Propel the Material, either by a Simple Reciprocating Motion down an Inclined Trough or by a more Complex Motion on the Level, and even Slightly Uphill.—The latest development of coal face conveyors is the reciprocating trough or *Rutsche*,¹ which, owing to its great simplicity, promises to make rapid headway, for if simplicity is always desirable in all machinery, it is especially so for appliances at the coal face, where all mechanical devices are more roughly used, and more subject to injury than in any other industry. The principle is simplicity itself, and one wonders why it has not been employed before. Such conveyors consist of an open sheet-iron flat-bottomed trough with slanting sides, or semicircular, supported by chains from the timbering, or from trestles, or by rollers from below. A reciprocating motion is imparted to such troughs either by hand or motive power, and as the original conveyors were inclined, being used in inclined seams, the material moved or slid forward and downward at the down-stroke, whilst it remained stationary at the up-stroke. The speed of travel depends on the method of support, the stroke, and the incline.

The oldest form is the suspended trough conveyor. With this system it must be borne in mind that the stroke must come to a stop when the supporting chains or links are in a vertical position, that is to say, the stroke must not extend equally on either side of the points of suspension, as then there would be no forward motion, at least not in a horizontal conveyor. The action is therefore as follows: When the conveyor is at rest all the supporting links or chains hang vertically down; as the stroke begins the trough is lifted, as it moves on the path of an arc described by the suspended links. During this motion the coal in the trough remains stationary; as the end of the stroke is reached the trough will be in its highest position, and it then begins the forward stroke. During this the coal likewise remains stationary, that is, moves with the trough; but as soon as the lowest point is reached the motion is reversed, but owing to the velocity imparted to the coal during the downward motion it slides on and does not come to rest till the trough has nearly completed its backward stroke. This motion is repeated again and again, and it is obvious that the length of the stroke and the pitch, if any, will materially

¹ This conveyor, having been introduced in German collieries first, the German name *Rutsche* (plural, *Rutschen*) is often used in this country, but the Author suggests "Jig-trough" as an expressive English name.

• affect the speed at which the coal travels in the trough. The links supporting the trough, it will thus be seen, do not travel at the forward stroke beyond their vertical position, the movement being regulated by the stroke of the pneumatic engine, which does not permit an extension of the movement.

The method of connection between the troughing and the engine depends upon the conditions. Where possible, the engine is fixed underneath the troughs and connected direct by means of a connecting rod. In thin seams, where this is not possible, the engine is placed on the side of the troughs, a cross-arm is attached to the engine and pivoted on a column, the connecting rod being attached to the cross-arm.

The aforesaid refers to conveyors suspended on chains or links either from the timbering of the roof or from special trestles.

If the trough is supported from beneath on rollers, and a sufficient fall be available, the rollers may move on the floor of the seam, or parallel with it on short lengths of upturned channel iron; but if the seam is level, or nearly so, these rollers must move on a path similar to that indicated by the suspended links, that is, short sections of rails or wedge-shaped wooden blocks must be provided, which begin at one end with a gentle incline which becomes steeper towards the end of the stroke. If a number of pairs of rollers are attached, running on such inclined rail sections, the behaviour of the coal in the trough will be the same as in the suspended conveyor, and it will be conveyed in the same way.

The troughs of these conveyors are best made of open hearth steel sheets from 2 to 4 mm. thick (14 to 9 B.W.G.), and joined up out of lengths of 10 ft. each. As to the width of these troughs, when first introduced there was a tendency to make them rather large, 24 to 28 in. wide and 12 to 13 in. deep; but these have been found unnecessarily large, and the best size has been found to be 16 to 20 in. wide and from 5 to 8 in. deep.

Coal face conveyors should work with as little noise as possible, and it has been found that small troughs well filled work more quietly than wider ones with a thinner load. It has also been found that conveyors of the smaller dimensions are quite capable of coping with the output of the seams, that is, keep pace with the men who load them.

At first most of the troughs were made of 2 mm. (about 14 B.W.G.) sheets, but it was found that they soon wore out, and if the plates were 3 to 4 mm. (about 10 to 9 B.W.G.), the total weight of the trough was naturally increased from 50 to 100 per cent., which made more powerful motors necessary. It was also found that the middle of the bottom of a flat-bottomed trough wore through first, so that the troughs had to be scrapped when the sides and a portion of the bottom were still good. A middle course was then adopted by some of the best makers, and the troughs were manufactured out of specially rolled sheets, which were thin at the sides and gradually thickened in the middle, in proportion to the relative wear as ascertained by experience. Semicircular troughs were made of similar sheets, fortified on the same principle by an extra thickness at the points where the wear was found to be most prominent. This method has the advantage that the weight of the trough is brought to a minimum and its lasting qualities to a maximum, and that the whole trough wears uniformly.

The methods of coupling up the different lengths of the trough of one long conveyor are very numerous. At first the practice was adopted of making the ends flanged, and bolting the units together with a narrow kind of fish plate on each side of the flanged joint; but these loose parts were constantly lost by the men, and the process had the disadvantage of being too slow. More modern methods include few or no loose parts, and allow a slight flexibility at the joints, so that curves in the level of the seam may be

followed by the conveyor. In suspended conveyors the weight of the trough itself has been utilised for tightening the joints by combining the links of suspension with a coupling device.

The details of the supports, both hanging and rolling, vary more or less in the machines of different makers, but the essential principle is the same, so that it is not proposed here to give much space to them, as the number of varieties is so great that it would require many pages to do them all justice.

The motors are nearly all of the compressed air type. Attempts have been made to use electricity as motive power, but the pneumatic principle is so obviously the most suitable that its retention is not to be wondered at. To use an electro-motor, a quick rotary motion has to be converted into a slow reciprocating motion, whilst the movement of the pneumatic engine with its slow reciprocating motion is so similar to that of the coal face conveyor that it may be coupled direct to it; therefore only those who have no pneumatic plant in their mine will consider electric drives.

Pneumatic engines are used either directly coupled to the conveyor trough by a connecting rod, the engine being fixed to the ground underneath, or they are coupled by the intervention of levers, rods, or cables. One of the latest methods is to fix the motor to the trough itself, and adjust the movement by a chain anchored at one end to the ground and at the other to the engine, which may be single or double acting.

Direct-coupled motors generally occupy less room, and are more easily shifted as the face recedes, whilst the initial cost is less than that of the gear-coupled motor; on the other hand, the former are more noisy, being fixed with the conveyor close to the coal face instead of some distance away (probably in the gateway). They must be moved every time the conveyor is moved, and, being placed under the conveyor, have a tendency to occupy more height, which may be an objection in working small seams.

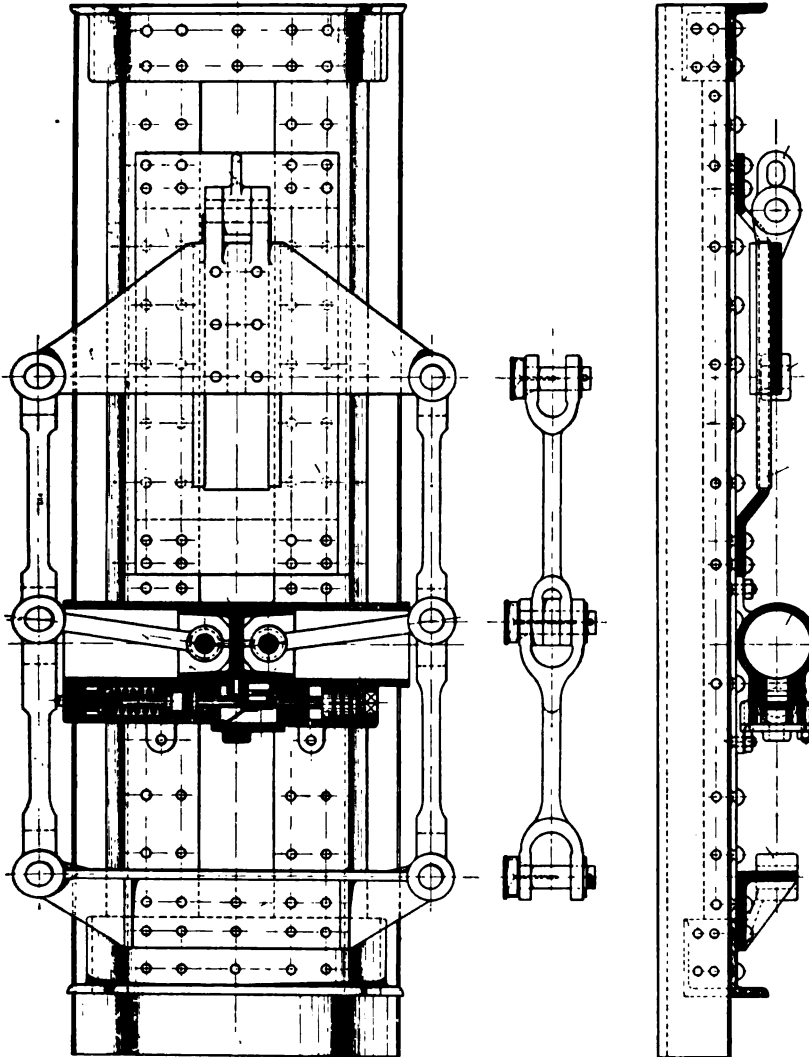
Both types of motors vary in the number and length of the strokes. For conveyors on an incline, where gravity is one of the conveying forces, direct-coupled motors are generally and preferably single-acting with a long stroke, as their action gives the coal a greater momentum, and therefore a greater forward movement at the change of the stroke; whilst for more horizontal conveyors, where gravity does not come into play, double-acting motors are better, with more frequent and shorter strokes. In order to adapt motors to all the conditions in the same pit, some of the types have been made with adjustable strokes.

The stroke given by the motor to the conveyor is from 6 to 16 in., and the number of strokes from 50 to 100 per minute; the speed of travel of the coal in the trough varies from 1 to 5 ft. per second.

Single-Acting Motors.—These can only be used for conveyors so situated that the motor has merely to lift or perform one half of the stroke, whilst the weight of the conveyor and its load are responsible for the return stroke.

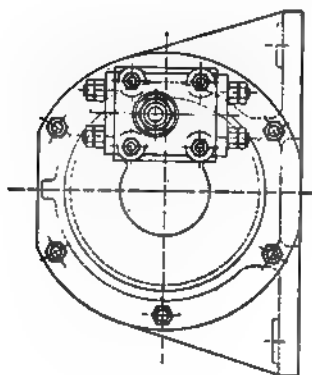
The first motor of this type was built by Gebrüder Eickhoff, and consists of a cylinder with piston and piston rod. The latter projects through one end of the cylinder and is coupled to a crosshead and two rods, the latter guided on both sides of the cylinder, and these two rods are again coupled by a crosshead which is connected up to the conveyor, directly or indirectly. If the inlet valve is opened, the compressed air enters the cylinder and forces out the piston rod, and with it lifts the conveyor and its load for part of the stroke, when the air supply is cut off and the stroke completed by the expansion of the air and the inertia of the moving conveyor. After the conveyor has come gently to the end of its stroke the gravity of the load exerts itself, so that the conveyor makes its return stroke automatically. At the same time the piston in the cylinder is reversed; before, however, the stroke is quite finished the air is automatically

admitted into the cylinder again. It will thus be seen that only one end of the cylinder is connected with the compressed air mains, whilst the other is open to the atmosphere. The valve gear consists of two trippers on the piston rod which manipulate the slide valve, so that either compressed air is admitted or the cylinder put in communication with the outer air.



Figs. 227 to 229. Flottmann Direct-Coupled Engine.

The latest Flottmann engine, which is fixed directly to the conveyor trough, differs materially from the foregoing, but is, strictly speaking, a single-acting engine. Figs. 227 to 229 give a good idea of the details of the working parts. The cylinder is open at both ends, and in it move two pistons connected by rods to the junction of two pairs of toggle levers. The illustration represents the two pistons at the beginning of their cycle of movements, that is, close together and with the port for the admission of compressed air open; the pistons are now forced apart, and with them the toggle levers. This action



Figs. 230 to 232. Korfmann Engine.

tends to move the two impulse brackets, to which the other ends of the toggles are joined, and as one of these brackets is anchored by a chain to the ground, and the other is bolted to the conveyor trough, the latter is forced to make its up-stroke. The air in the cylinder is now allowed to escape, and the weight of the trough, acting on the toggles, forces the pistons back to the first position.

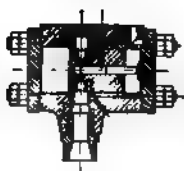
The working of the gear is as follows: As the pistons are forced apart, and when nearly reaching the end of the stroke, one of them uncovers a port leading to a small auxiliary cylinder with piston, rod, and slide valve, the latter at the extreme end. As a portion of the air now enters behind the piston, the slide valve is pushed forward and cuts off the air supply to the main cylinder. The movement of the slide valve at the same time pushes a rod out at the opposite end, and when the weight of the trough completes the return stroke, one of the collapsing toggle levers pushes this rod back again, thereby reopening the inlet for the compressed air, and at the same time pushing the small auxiliary piston back to its first position.

The impulse bracket, which is anchored by the chain, is guided by a sliding block and groove fixed to the conveyor trough to ensure the movement of the toggle levers being symmetrical.

Double-Acting Motors are all those which admit compressed air alternately on both sides of the piston, and which move the conveyor in both the forward and backward stroke. The valve or slide gears are either inside or outside the cylinder, and consist of various forms of valves and slides. The cut-off is always so arranged as to utilise the expansion of the air, whilst a few are on the compound system.

The Korfmann Conveyor is one of the latest types. It is supported on wedge-shaped runners, which can be placed in a variety of positions to suit level or inclined seams.

The engine is noteworthy for its comparative simplicity. Figs. 230 to 232 show this in section, also a separate section of the slide box in the second position, and an end view. Normally the slide valve (shown in the upper section) rests, owing to its own weight, in the lowest position. As the compressed air is admitted, it passes round the annular channels in the gear box and cylindrical slide valve and through radial openings into the central passage and port behind the piston, pushing the latter forward. The



cylindrical portion or piston of the slide gear is compounded, and consists of the lower main portion fitted with an upper wing, and has in addition a small plunger in its lower end. Two small openings may be seen in the main cylinder near the back and front ends; these communicate by means of channels with the valve box. As soon as the main piston has uncovered the first of these openings, some of the air passes under the piston of the slide gear and raises the same (see lower section), thereby cutting off the air supply. The main piston completes its stroke by the expansion of the air in the cylinder, and at the end of the stroke uncovers an exit (not shown in the illustration) for the air. In the second position (see lower section) air is admitted over the small lower pin-like plunger, which is pressed down, holding the remainder of the cylindrical slide block up. In this position air is at the same time admitted to the front end of the main piston, which thereby makes its return stroke. During this, as soon as the piston has closed the first of the ports, the enclosed air in front of the piston is compressed and forces the valve piston back into its first position again, new air being then admitted for the next stroke, and the same cycle repeated over and over again. With this engine the stroke can be varied by turning a semicircular disc which retards or accelerates the exit of the air.

Working Expenses.—As regards working expenses of reciprocating coal face conveyors (Rutschen), capacity, etc., the most reliable information available has been compiled by Arthur Gerke, a well-known engineer of Bochum, Germany, from his own tests, and from observations of cases which have come under his own notice in German mines. He says, when referring to the consumption of compressed air per minute, that the statements of the manufacturers of the different plants are very confusing. The quantity of air used, he says, does not so much depend upon the length of the conveyor, as on the condition of the coal. If large coal is handled the air consumption is much less than when dealing with fine coal, likewise the consumption is less with dry than with wet coal, and Mr Gerke attributes this circumstance to the greater friction caused by fine coal and wet coal. In addition to these considerations, the consumption of air is variable with the number of strokes per minute.

The following table¹ is a *résumé* of air consumed, but as the quantity of coal handled

CONSUMPTION AND COST OF COMPRESSED AIR FOR DRIVING RECIPROCATING
COAL FACE CONVEYORS, OR RUTSCHEN

System.	Diameter of Motor Cylinder in Inches.	Pressure in Lbs. per Inch.	Consumption of Air per Minute in Cubic Feet.	Cost of Compressed Air.		Length of Trough in Feet.	Incline of Seam in Degrees.
				Per Cubic Metre ² at the Pressures given in Column 3.	Per Ton of Coal Conveyed.		
Carlshütte ³ -	8	68-75	70½ ⁵	·05	1·2	525	15
" -	10	45	70½ ⁵	·0375	·1375	131	20
Flottmann -	8	45-60	18	·25	1·0	262	3-20
" -	10	75	16	·025	·281	229	2-5
" -	11½	45-60	26	·187	·225	164	2-12
" -	11½	75-90	18	·1625	·2275	262	2-12
" -	14	75-90	21	·1625	·2725	238	2-12
Würfel & Neuhaus	10	52	...	...	1·875	210	22
" "	12	45	...	·3125	·9	394	13
" "	12	75	41	·125	·75	262	0-5
Eickhoff -	9	38	18	·156	·46	295	0-15
Degenhard -	6½	60	76	·187	1·5	328	0-10
Hinselmann -	6½ ⁴	38	43	·156	·968	295	0-15
" -	9	60	14	·225	·2625	328	10

¹ From "Ueber Abbauförderung," by Arthur Gerke.

² 1 cubic metre = 35·3166 cubic feet.

³ The motors are not of the latest type.

⁴ Twin motors.

⁵ Air not under pressure when measured.

was not taken into consideration, the result does not in any way prove the superiority of one conveyor over another, and only serves as a guide to the approximate air consumption.

The variation of cost in the above table of compressed air per ton of coal handled is from 0·1375 to 1·875 pence. In Germany it is considered that 5 pfennige or 0·625d. is a reliable average figure.

Experience gained in German collieries shows that the life of a compressed air motor is about five to six times as long as that of the conveyor trough, whilst that of an electro-motor is about ten times as long, so that the wear and tear of the motor may be calculated to be from $\frac{1}{2}$ d. to $1\frac{1}{2}$ d. per ton of coal handled. From observations in the working of a large colliery, where many such conveyors are at work, it is safe to assume that :—

A trough of 2 mm., 14 B.W.G., will handle 30,000 tons of coal and 18,000 tons of dirt.					
3	11	50,000	30,000		
4	9	70,000	40,000		

The dirt or spoil which is mentioned above is not of a cutting nature, and the figures given are for the life of the trough.

It is calculated that the cost of the wear on the trough works out at from $\frac{1}{2}$ d. to 1d. per ton of coal handled.

The working expenses tabulated from the above experiences with these conveyors in Germany, per ton of coal handled, are as follows :—

	Per Ton of Coal Handled.
Driving power - - - - -	·625 penny
Wear on motor - - - - -	·125 „
Wear on the trough - - - - -	·625 „
Lubricant - - - - -	·1 „
Repairs - - - - -	·375 „
Cost of erection and re-erection - - - - -	·625 „
	<u>2·475 pence.</u>

Gate Conveyors.—Where two coal faces are worked on to one main gate, the coal filling is concentrated in one place, and it will then pay to put in an additional conveyor, known as a gate conveyor, large enough to take the output of the two face conveyors. Under these conditions the roadways do not have to be ripped to leave head room for the tubs, and the coal is conveyed direct from the face down the gate to the main road, or to where the gate is already wide and high enough to take the tubs. The delivery end of the conveyor is fixed, the other end being gradually extended as the faces advance. A gate conveyor can be used up to 150 yards long, beyond which another can be installed to deliver into the first one.

Concluding Remarks.—Belt and scraper conveyors require less driving power than reciprocating trough conveyors (Rutschen). In other respects they are about equally as serviceable, but the latter are generally of a lower initial cost. Concerning the respective merits of Rutschen, those suspended on chains or links are more difficult, and therefore more costly, to move with the face ; they depend on the timbering, and their use is restricted to seams of certain limits. The type with independent trestle supports are more costly still in labour for moving, and also share the restrictions as to size of seam with those previously mentioned, but they have the advantage of being independent of the timbering of the mine.

Those supported on rollers are the least expensive and simplest to move, are independent of the timbering, and are applicable to the smallest workable seams. From the above it appears likely that conveyors of the roller supported type will soon become as popular in this country as they are already on the Continent, where they are very largely used.

CHAPTER XIV

CASTING MACHINES

CASTING machines are, to all intents and purposes, conveyors ; they receive their load of iron in a liquid state at one terminal and deliver it at the other in the form of pig iron. The receptacles for the metal form at the same time the moulds for the pigs. The fundamental principle is that of a continuous bucket conveyor, built on lines to conform with the enormous duty they have to perform, and as they deliver at the terminal only, the units or moulds are rigidly connected with the links of the two chains to which they are attached.

Casting machines were first introduced in the United States and it is estimated that over 50 per cent. of the pig iron is handled by such machines. Of late years a few of these installations have been introduced into this country and on the Continent.

The chief advantages of mechanically casting and conveying pig iron consist in an enormous saving of labour, and also in the production of sandless pigs, as well as saving the large space occupied by the "pig bed." In America such pig iron commands a premium of 1s. to 1s. 6d. per ton above pigs cast in the ordinary way, because, melting more easily, it requires less fuel in the cupola. Mechanically cast pigs are smoother and cleaner, more homogeneous, and of more uniform size. Further advantages are claimed in that the furnace can be tapped whenever it is most convenient, while the whole output is cooled and delivered into trucks without being touched by hand.

One of the principal advantages, as far as labour is concerned, is the avoidance of the clearing of the pig bed by hand labour, which is exceedingly arduous, and in the hot season of the year the men are not infrequently overcome by it, but with the advent of the lifting magnet, which is used for this purpose with great success (see chapter on Grabs), the casting machine no longer monopolises this advantage.

The disadvantages are that the iron suffers in fracture, that is to say it deteriorates in point of texture, which is due to the chilling effect of the mould and the subsequent submersion in water, as well as to the vibration of the mechanism during the solidification of the iron in the mould. And lastly, the breakdowns which are inherent to all machines. (The chilling of the pigs may or may not have an injurious effect upon the later use of the iron, and it is believed that for steel making it is no detriment, but when the iron is bought by fracture it might affect its market value.)

As yet only a few of these installations are at work in this country, the first being probably that erected in 1898 at the works of the Millom and Askam Hematite Iron Co., Millom, who adopted the "Uehling" machine, the use of which has, however, been discontinued. The second plant was that introduced by the Palmer Shipbuilding and Iron Co., Jarrow-on-Tyne, in 1899, at their Cambrian Works, the "Heyl and Patterson" machine. These two devices are similar in design, the principal difference being that in the case of the "Heyl and Patterson" machine the pigs are cast in moulds whilst partly submerged in water. There is also a minor detail in the device adopted for preventing the adhesion of the pigs to the moulds. To guard against this the moulds are in the

"Uehling" process coated with a spray of lime water, whilst in the "Heyl and Patterson" machine they are coated with soot.

There are two further types of casting machines, the "Ramsay" and the "Hawdon." The former is unlike either of the two first-mentioned appliances, in so far as the moulds are placed round the circumference of a large revolving table. The "Hawdon" machine is partly in a straight line and partly in a circular form. Several "Hawdon" casting machines are at work in this country and on the Continent, as well as in America.

The great difficulty in the mechanical handling of molten metal lies in the enormous weight of the metal, moulds, chains, etc., to say nothing of the great heat. Devices for this purpose must be exceedingly rugged, so that they may suffer as little as possible from

the heat to which they are subjected, and from the weight they have to carry. The expansion of parts of these machines, caused by the heat, the resultant excessive wear and tear, as well as the difficulty of keeping them lubricated, was found a serious obstacle by their builders. The moulds last only about nine months, and in addition to this great wear and tear on the machines the fracture of

the pigs produced by them is spoiled, and as in this country iron for foundry purposes is generally sold by fracture and not by analysis, it does not find so ready a market.

The "Uehling" Casting Machine.—

This machine consists of two casting and one cooling conveyor, the latter taking the pigs from the two former, as shown in

Figs. 235 and 236. Feed Terminal of "Uehling" Casting Machine.

Figs. 233 to 237. Each of the two casting conveyors is about 125 ft. long, and consists of 260 moulds. The moulds travel upwards at an incline of 9°, and are carried over sprocket wheels at each end. The conveyor travels at such a rate as to give each mould ten minutes to pass from end to end. This allows the iron sufficient time to solidify before reaching the other terminal. The pigs are then precipitated down two shoots leading to the tank of the third conveyor, which is nearly 100 ft. long. This third conveyor is of the articulated band or apron type and travels in a tank for a distance of about 70 ft., the water being deep enough to cover the pigs as they lie on the conveyor. The pigs are carried through the tank, and are raised at the other end to a sufficient height to be lowered into railway trucks. The different charges of the furnace being successively cast with this machine, the moulds are kept thereby at a low red heat.

¹ *The Engineer*, 4th August 1899; *Engineering and Mining Journal*, 5th January 1901; *Iron and Coal Trades Review*, 25th November 1898 and 2nd June 1899; *Stahl und Eisen*, 1897, No. 16; 1898, No. 13; 1900, No. 1.

'works.

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To prevent the metal adhering to the moulds, they are coated by a spray on their return journey to the pouring pot. The capacity of the machine is 1,500 tons per day of twenty-four hours.

The "Uehling" machine at the Bethlehem Steel Co.'s Works, U.S.A., is 165 ft. long and travels at the rate of 22 ft. 6 in. per minute up the usual incline, the moulds being spaced at a pitch of 12 in. It is driven by a 40 H.P. electro-motor, and the capacity is twenty-three pigs per minute weighing 110 lb. each.

The "Heyl and Patterson" Casting Machine.—This device, which is here illustrated, has a capacity of 1,500 tons in twenty-four hours. It consists of a steel frame, combining a water tank with an upper and lower track, upon which runs the chain carrying the pressed steel moulds into which the liquid pig iron is poured through the

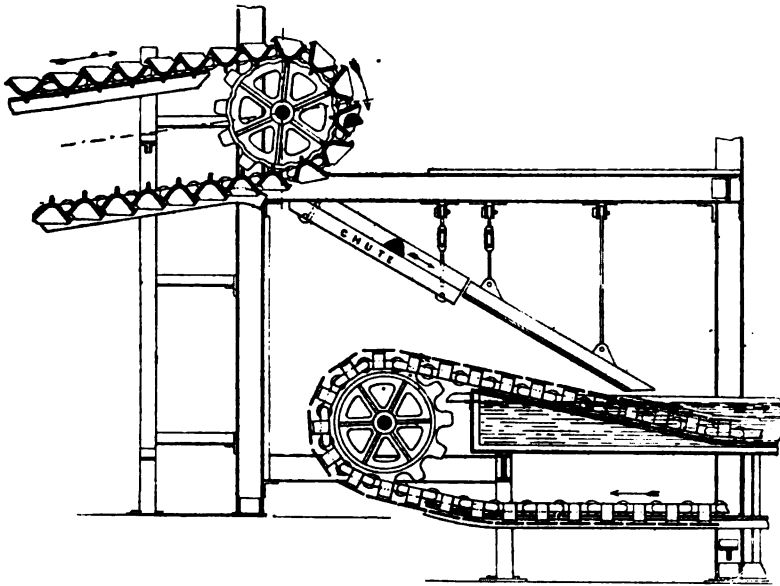


Fig. 237. Delivery of the Pigs from Casting to Cooling Conveyor.

intervening runners. These are so arranged that the two or more rows of moulds can be fed simultaneously.

The principal feature consists in this, that the pouring of the metal takes place into moulds whilst partly submerged in the water contained in the tank. The moulds travel in that condition for a sufficient length of time to allow the metal to solidify, after which they are quite submerged and travel through the tank to nearly the other end of the machine, at which point the chains run up a slight incline to the loading end.

The moulds on their return journey pass over two furnaces in which crude oil or similar material is burning, and being still damp, readily receive a covering of soot which adheres to their interior and lips. The heat of the furnace also serves to so complete the drying of the moulds that they are ready for refilling.

Fig. 238 is a general view of the machine looking towards the delivery end, which shows clearly a portion of the moulds partly submerged.

Fig. 239 is a view of the delivery end. The two strands of moulds are driven from

one shaft by spur wheels, and are fitted with friction clutches so that either one strand or both may be used.

Fig. 240 represents two furnaces for drying and coating the moulds. These are mounted on wheels and can be withdrawn when the machine is out of work. The moulds as they leave the water tank travel up an incline sufficiently high to give easy discharge for loading into empty wagons, each being fitted with a pair of runner wheels, 8 in. in diameter, similar to the machine previously described.

The chain consists of links of a 24-in. pitch which are joined together by pins 2 in. in diameter. The conveyor is not so long as in the "Uehling" machine, and the power consumed is 14 H.P.

Fig. 238. "Heyl and Patterson" Machine looking towards Delivery End.

The "Ramsay" Casting Machine.—This was built for the Tennessee Iron and Railroad Co., Birmingham, Alaska, U.S.A., and varies considerably in form from those previously described, though the principle itself is very similar. The "Ramsay" machine consists of a mild steel table of an annular form, the sides being of sheet steel, and riveted together with angle irons. The intervening space is intercepted periodically by steel stays. This circular table rests upon eighteen pairs of wheels, the axles being supported by bearings bolted to the table. A section through the table itself with its supports is shown in Figs. 241 and 242.

The moulds which receive the liquid metal are fitted with small trunnions which fit into a pair of bearings on the rims of the circular table. The inner periphery is fitted with toothed segments, which form a complete circle for the

purpose of revolving the whole apparatus. The toothed segments, which gear with the driving wheels, are shown in *a*, Fig. 241.

Figs. 243 and 244 represent the casting machine in elevation and plan. The latter also shows the engine coupled to three shafts, to the ends of which small spur pinions are keyed which cause the table to revolve in the direction of the arrow.

The filling device is shown in Fig. 241. The metal is poured first from a ladle into a shoot *A*, by which it reaches the revolving filling drum *B*. The latter is driven by spur wheels, and the other side remote from the drive is supported by three rollers fixed to the bracket *C*. Both *A* and *B* are lined inside with fireclay. The drum *B* has six radial apertures, and is caused to revolve at exactly the same circumferential velocity as the moulds, so that the six exits are, so to speak, in pitch with the moulds, and the spilling of iron is thereby avoided, even if the moulds do not overlap each other, as is usual in some

Fig. 239. Arrangement of Discharging End of "Heyl and Patterson" Machine.

Fig. 240. Drying Furnaces for Moulds in "Heyl and Patterson" Casting Machine.

casting machines. The liquid metal is cooled by sprays of water from a pipe which is shown in Fig. 243. The delivery point is shown in Fig. 245. A short length of tooth-rack *b* engages with the wheel keyed to one of the trunnions of each mould for the purpose of reversing it. At the moment of tilting, each mould receives a series of taps at the back from three hammers shown in the illustration.

Immediately behind the tipping device there is an appliance on the principle of an injector. This coats the interior of the moulds with lime water similar to the process employed in the "Uehling" machine.

The railway wagons in which the pigs are loaded are brought to the point of delivery through a cutting in the ground, as seen in Fig. 243.

The "Hawdon" Slag Casting Machine.—This is the design of Mr William Hawdon, who has for some years been connected with Sir B. Samuelson & Co.'s Newport Iron Works, Middlesbrough. Fig. 246 gives a longitudinal view of the machine. AA are two endless chains made of long steel links fastened together by pins or rivets. B is the driving shaft. C are the two pulleys over which the endless chains pass. These pulleys are driven from shaft B by geared wheels.



Figs. 241 and 242. Filling Device of the "Ramsay" Casting Machine.

The moulds which carry the slag are shown in plan and cross section in Figs. 247 and 248 as fixed to the chains. It will be seen that they are bolted on to a chain A by means of lugs on the under side.

The endless chains move in the direction of the arrow *a*. The slag is conveyed from the furnace by means of a trough F, whence it flows into the moulds which pass beneath it, then through the tank D, and on over the pulleys E. As the moulds pass over these pulleys the slag is tipped out in trucks, tip wagons, or other suitable vehicles, and is further cooled by means of water sprinkled from pipe H fixed over the truck F¹.

To take up any wear in the chain, a worm and worm wheel are placed at JKL. These are connected by means of links MN to the spindle of the terminal E, and the attendant can at any time adjust the chain as required:

This machine was originally devised for the purpose of saving the labour which is entailed in breaking up slag balls and wheeling them, by means of barrows, into hopped barges for conveyance to sea, there to be tipped. But it is equally adaptable to cases where the slag is deposited on the ordinary slag tip or mountain.

The saving of labour and of the wear and tear of plant as against the ordinary

method of running into balls is claimed to be very considerable. The slag thus made is moreover suitable for breaking into road metal, and especially for concrete, some thousands of tons having been sold for that purpose.

The "Hawdon" Casting Machine.—The machine illustrated in Figs. 249 and 250 is by the same designer as the machine previously described.

The general arrangement of this pig-iron casting machine is much the same as that of the older type of slag machine, but it has been constructed more particularly for dealing with iron, and also with a view to keeping the moulds dry on their return for refilling.

The moulds in the slag machine are dipped in water, while in that for iron they are kept dry. A secondary machine of circular shape is used for the cooling process. The pigs, when cool, are discharged from the circular conveyor, and ascend the elevator into railway wagons, as shown in the illustration.

The moulds attached to the chain are very similar to those previously described. On each one is cast a lip to prevent the flowing iron from falling between them as they pass in succession to the mouth of the tilting ladle.

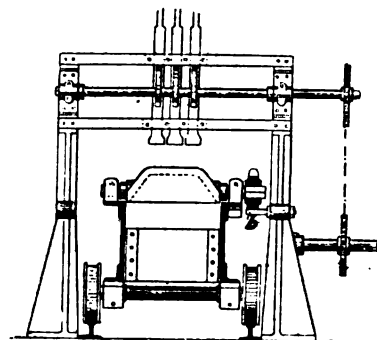
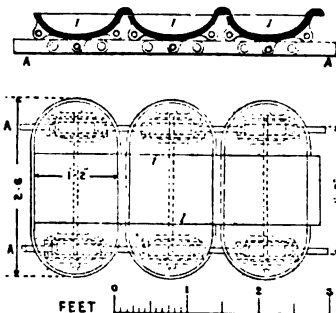


Fig. 245. Delivery Point of "Ramsay" Casting Machine.

Mr Hawdon has specially provided for the heavy weight to be carried. He has not attached the rollers to the moulds themselves, but has fixed them to the framework, allowing the chain to run over the rollers, the bearings being of brass, and at such a distance from the hot moulds as to allow of the free use of lubricant.

The supporting rollers are placed at frequent intervals, thus preventing any undue wear on the chains. This applies as much to the circular conveyor, on which the pigs are cooled in a tank of water, as to that in a straight line in which they are cast.

It is important to notice that all the bearings in the circular conveyor are above water, and are therefore accessible. With regard to the removal of the pigs from the circular conveyor to the wagons, it may be noted that, as they move round under water with the conveyor, they come in contact with a fixed plate or plough which pushes them off and into the elevator which delivers them on the wagons placed alongside.



Figs. 247 and 248. Moulds of Hawdon's Slag Casting Machine.

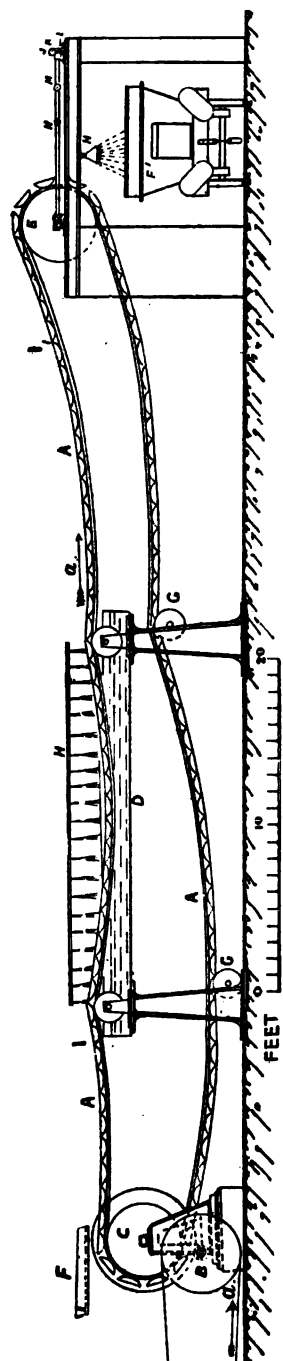


Fig. 246. Longitudinal Elevation of Hawdon's Slag Casting Machine.

Fig. 251 represents this elevator as used for loading the pigs from the cooling conveyor.

Figs. 252 and 253 give some of the details of the conveyor itself.

The lettering given below describes the different parts of the machine, and refers to Figs. 249 to 253.

A. Moulds. B. Chain carrying moulds. C. Brass block fitted into chain to take the wear of the pin. D. Rollers carrying chain. E. Brass bearings for roller shaft. F. Spout to convey metal from ladle to moulds. G. Shoot to convey pigs to cooling conveyor. H. Table of circular conveyor or cooler. J. Inclined plate or plough, which removes pigs from cooling conveyor to elevator. K. Elevator which lifts pigs into trucks from cooling conveyor. L. Fixed bars between which the elevator works. M. Rake of elevator. N. Shoot. P. Clutch for driving elevator. R. Sprocket wheels.

The Casting Machine of the Iron Works of the Aplerbecker Hütte. — This was built by the Deutsche Maschinenfabrik A.G. The essential features of this machine consist of two comparatively small turntables placed close together, the outer circumferences of which are fitted with tipping moulds for the iron. The liquid metal is led to these turntables by an oscillating trough with two side and one end outlets. This trough receives a rocking motion round its longitudinal axis, so that the two side outlets discharge the metal into the receptacles of each table alternately. It will thus be seen that the tables (each of which has 64 moulds on its circumference) are stationary during the pouring process, and whilst the mould of one is filled the other table is moved forward presenting a fresh mould to the rocking shoot, which is immediately reversed and fills it. When the moulds have passed 270°, or three-quarters of a revolution of the table, and the iron has congealed, they are here turned upside down and tapped to release the pig into an iron wagon underneath. The moulds remain in their inverted

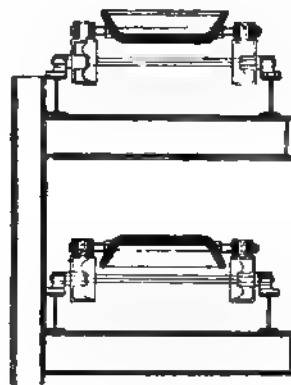
FIGS. 249 AND 250. Plan and Elevation showing General Design of Hawdon's Pig-Iron Casting Machine.

position for the remainder of their journey, during which they are coated with a spray of lime water.

Unlike the Ramsay machine already described, which has about 200 moulds in its

Fig. 251. Appliance for Loading Figs from Hawdon's Casting Machine.

circumference, and which runs on rails, the present machine is supported by a very powerful central upright shaft, from which the annular table is suspended by steel



Figs. 252 and 253. Details of Moulds and Chains in Hawdon's Casting Machine.

structural work, and in addition is supported by rollers. The outer trunnion of the moulds carries a star-like attachment which encounters on its journey a fixed tripper at the discharging point, which inverts the moulds, and a bent channel keeps them in this position until another tripper just before the pouring point brings them into their original position ready to receive another charge.

All the movements are actuated by hydraulic machinery. The turntables revolve by means of an oscillating pawl engaging a toothed wheel.

Should any hitch occur to either of the turntables during the pouring of the metal, the driver of the machine can set the pouring trough into a middle position and discharge the metal by the end shoot already mentioned and let it run into an emergency "pig bed" beyond the two turntables, so that the rest of the iron in the pouring pot can be disposed of.

A machine on the same principle has since been built by the same firm for the Westphalian Iron Works which is reported to be a success, the only difference being that hydraulic power, as in the former, has been discarded in favour of electricity.

CHAPTER XV

MISCELLANEOUS CONVEYORS, MOSTLY FOR SPECIAL PURPOSES AND NOT CLASSIFIABLE UNDER ANY OF THE PREVIOUS CHAPTERS.

Roller Conveyors, Live Rollers, or Roller Trains.—These differ from roller runways in the important detail that the rollers are mechanically driven, and the rotation of the rollers carries the material forward, either on the level or on an upward or downward gradient, whereas in the roller runway (see p. 203) the object to be transported travels by its own gravity over a series of rolls, down an incline, the load revolving the rollers as it passes over them.

Roller ways without driving power can be, and indeed are, used on the level or incline in connection with rolling mills where red-hot girders newly rolled are pushed over such roller ways, but in these cases the rolling mill furnishes the driving power and conveys it to the small rollers by the object itself, the rollers merely reducing friction or resistance which would otherwise be offered to the progress of the rolled bar, girder or rail.

Power driven roller conveyors are used in plate glass factories, in rolling mills for handling ingots, and in engineering works, to take away the products of cutting shears, saws, or other machine tools; carrying away objects in course of manufacture which are too heavy or bulky to be easily removed, and which, if not continuously cleared away, would encumber the machine tools producing them. The upward gradient for these roller conveyors is limited by the amount of friction between the rollers and the material.

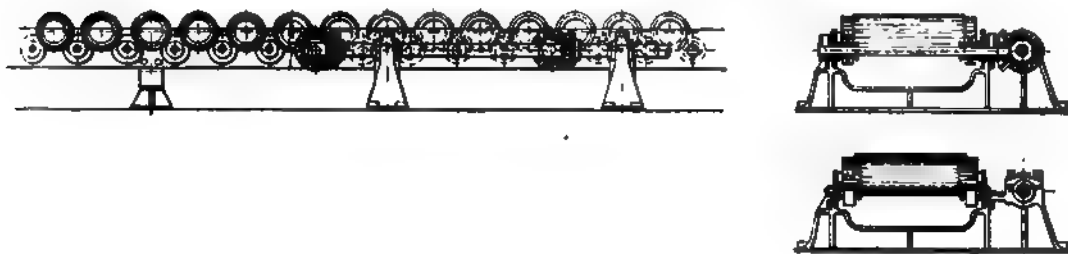
The original type of such roller conveyors is exceedingly simple in principle, but not in construction. The rollers are placed fairly close together and each is driven by a pair of bevel wheels from a small shaft which runs alongside at right angles to the roller spindles and forms a portion of the conveyor. The rollers, of course, all revolve in the same direction and must therefore not touch each other. The difficulty in the construction is principally due to the close proximity of the parts to each other, and as the driving wheels should be smaller in diameter than the rollers, in order that they should not project above them and thereby obstruct the passage of the material conveyed, or be exposed to damage, the rollers must either be larger than would otherwise be necessary, or the wheels must be very small.

The "Thomas" Roller Conveyor.—A great improvement in this type of conveyor has been made by the Belgian engineer, A. Thomas, who has overcome the difficulties above referred to as will be seen from the conveyor illustrated in Figs. 254 to 257. Here the rollers are all loose, *i.e.*, they do not run on axles or bearings, but revolve on rotating rings, every fifth or sixth pair of rings being driven by a pair of mitre wheels; the rings with their driving spindles being on a lower level than the rollers, give ample space for fair sized mitre wheels without their projecting above the carrying plane, level with the top surface of the rollers. The upper of the two cross sections shows one of the driven pair of rings, while the other cross section shows a pair of the loose rings, unconnected with driving power. The working of the conveyor depends on the driving

power that is imparted to one pair of rings being conveyed by one of the rollers placed loosely upon this pair and the next, so that the next pair of rings is revolved by the roller resting on top; in like manner is the rotating power transmitted by the second pair of rings to the second roller placed upon them, and the third pair, and so on. The rollers are reduced at both ends where they rest on the rings, so that the material conveyed cannot damage the surface which revolves on the rings.

The advantages over the old type are smooth running, and therefore smaller expenditure of driving power, smaller initial cost, and infinitely less expenditure for repairs, for if one of the rollers should be broken or damaged it can simply be lifted out and a spare one dropped into its place.

One of these conveyors has been in use at the works of the Société Anonyme d'Ougrée-Marihay since 1909; it is 225 ft. long, and consists of 277 rollers, each 8 in. in diameter, and placed at a pitch of 10 in., every seventh pair of rings being fitted with



Figs. 254 to 257. The "Thomas" Roller Conveyor.

a driving wheel. The material conveyed is bloom crop cuttings, and the driving power required is 20 H.P.

Bolinder Timber Conveyors.¹—These are made on the same principle as the live rollers or roller trains, only as the timber so conveyed is always in long lengths the rollers are much further apart.

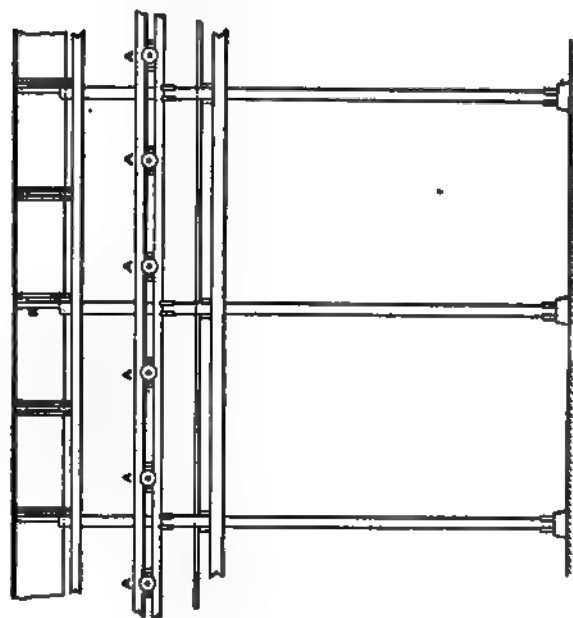
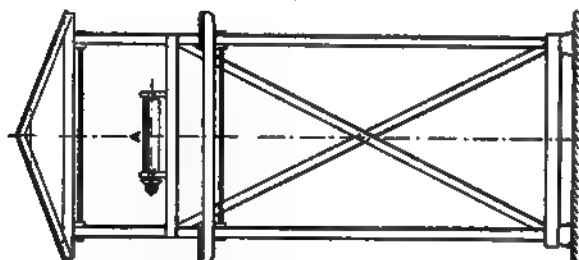
A conveyor of this type was in use at the Millwall Docks for many years for conveying boards, but unfortunately it was destroyed by fire in 1912. These conveyors are somewhat on the principle of a band conveyor; but whereas in the band conveyor the band is driven, and causes the supporting rollers to revolve, in the Bolinder conveyor the rollers are made to revolve, and thus propel the boards placed upon them. Figs. 258 to 260 show a section through the conveyor on its supporting structure, with the elevators which lifted the boards on to the conveyor; also another section and a longitudinal elevation of the conveyor.

The rollers AA were of cast iron, and 10 in. in diameter by 2 ft. 6 in. long, pitched 5 ft. apart, and driven by a small steel shaft about 1 in. in diameter, running the whole

¹ *Timber Trade Journal*, 13th July 1901.

length of the conveyor, each roll being geared to this shaft by a pair of bevel wheels with a ratio of about 3 to 1.

The rollers projected slightly through the bottom of the trough, in which the boards



travelled at the rate of 150 to 200 ft. per minute, the rolls themselves making 60 to 80 revs. per minute. The boards to be conveyed must be more than 10 ft. long, so as always to rest on not fewer than two rollers.

These conveyors are very simple and effective, the most remarkable feature being that their construction admits of their negotiating curves. (The one at the Millwall Docks described several curves having radii of 170 to 190 ft.) The steel driving shaft is sprung into these curves and appears to work well, though no doubt it consumes more driving power than the straight lengths. There is a separate electro-motor of 5 H.P. for every unit of 500 ft. of length, the motor itself being placed half way. Successive lengths of 500 ft. are needed to convey the timber at 180 and 200 ft. per minute respectively.

These devices will deliver about 200 standards¹ of 5-in. by 7-in. "battens" in ten hours, and other sizes in proportion.

FIG. 260

Figs. 258 to 260. Bolinder Timber Conveyor.

A general plan of that portion of the Millwall Docks where the Bolinder conveyor was at work is shown in Fig. 261. The line indicated by arrows illustrates the complete conveyor with all its curves.

¹ One standard of wood is 120 pieces 12 ft. long by 11 in. wide and 1½ in. thick, or its equivalent, i.e., 165 cub. ft. of timber. 3·3 loads of 50 cub. ft. make one standard.

A photographic view of the same conveyor is represented in Fig. 262, while Fig. 263 represents the delivery appliance by means of which the planks are lowered to the

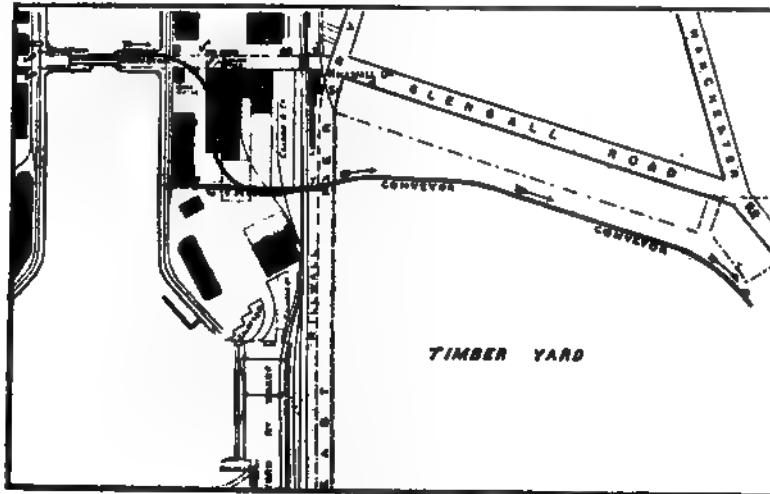


Fig. 261. Bolinder Conveyor at Millwall Docks.

ground. It is movable and runs on a single rail, so that it can be put into any position.

Fig. 264 gives a photographic view of the same lowering device.

Fig. 262. Bolinder Timber Conveyor crossing Great Eastern Railway and East Ferry Road.

A portable conveyor on similar lines is built by Messrs Bolinder, movable on wheels, for use in timber yards. Figs. 265 and 266 illustrate this appliance, which practically explains itself, its principal feature being that it is built in such a way as to allow of its temporary erection at different parts of the timber yard. The time taken in connecting,

say, 100 ft. of this conveyor would be about twenty minutes. The device is built in sections (one of which is represented in the illustration). They are each 20 ft. long, and are joined together by steel cotters. The respective lengths of shafting are also coupled together, the end of each length being square, and fitting into a square socket

on the succeeding length of shafting. These conveyors will deliver about 100 standards of 3-in. by 7-in. "battens" in ten hours, while the capacity on other sizes of timber would be in proportion.

The same firm have also recently introduced a new timber conveyor which appears to be a great improvement on the old one. It consists of an endless chain which runs over two terminal pulleys of suitable design. The chain itself consists of a series of rollers, the distance from roller to roller being about 3 ft.

Fig. 267 shows details of the chain; also special link with rollers.

Fig. 268 shows a portion of the conveyor as mounted in the timber yard.

It will be readily understood that as the conveyor is set in motion, the rollers, which run on supporting timbers, revolve, whereupon the timber to

Fig. 263. Lowering Appliance in connection with Bolinder Timber Conveyor.

be conveyed is not only carried by the rollers, but is also pushed forward by virtue of the revolution of the rollers, so that its progress is considerably accelerated. The chain has a speed of 90 ft. per minute, and the timber is conveyed practically at 180 ft. per minute. These conveyors are built in lengths of 1,000 ft., with one driving gear. Such a length is said to take 6 H.P. to drive. The total length, composed of coupled units of 1,000 ft., is unlimited, and if driven by electro-motors the driving arrangements will require very little preparation. They pass round curves with a radius of not less than 150 ft. for deals 30 ft. in length by 1 ft. wide. Longer boards would require a greater radius in proportion.



Figs. 265 and 266. Portable Timber Conveyor.

In addition to the advantage already mentioned of greater speed of delivery, they have the further advantage that both top and bottom runs can be used for conveying. It is obvious that when two or more units are coupled together the timbers will readily travel from one to the other; but where the lower run is also to be used for conveying, small auxiliary conveyors are used to remove the timber from the lower run past the terminals to the lower run of the next conveyor.

Fig. 264. Photographic View of Lowering Device in connection with
Roller Conveyor at Millwall Docks.

The capacity of this new conveyor is 160 standards in ten hours.

There are many other devices in use for handling timber, principally in the timber districts of America and in the vicinity of the Baltic Sea. These are not, however, individually described, as they do not present any new features. They are all more or less of the same type as the trough cable conveyor, and work in pairs or in greater numbers. The attachments are so pitched as to simultaneously engage with beams or planks, and so convey them up inclines or in a horizontal direction. Very frequently

pitch chains are used instead of cables, when the attachments are not in the form of discs, but rather in the shape of claws (see page 69).

Conveyors for Bottling Stores, etc.—Among the smaller industries into which conveyors have found a ready introduction is the bottling industry. The principal ones used are the roller runways and the slat or tray conveyor.

Fig. 269 illustrates a double service conveyor installed in the bottling stores of the Manchester Brewery Co., Ltd. An unusual feature in this case is the bight standing out at right angles to the main body of the conveyor. The chain used is of the Dodge cable

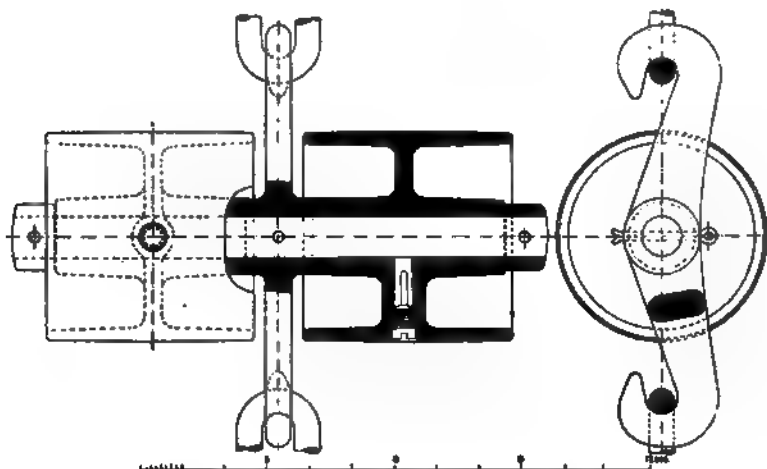


Fig. 267. Latest Type of Bolinder Timber Conveyor.

type with renewable malleable-iron bearing blocks. This chain, being flexible in two planes at right angles to each other, is not compelled to move in a horizontal path. Thus the direction of motion may be partly horizontal and partly inclined, and the axes of

Fig. 268. Latest Type of Bolinder Timber Conveyor as used in Timber Yards.

the terminal shafts may also be inclined, though usually vertical. It is driven by a 5 H.P. direct current electro-motor, and was erected by the Ewart Chainbelt Co., Ltd., Derby.

Another interesting example of a double service conveyor is in a mineral water factory.

In this instance one run traverses the centre of the factory while the return run travels along an external loading-out stage, from which motor wagons receive their supplies. Thus the same conveyor is utilised both to take returned empties into the building and to carry full boxes to the various vehicles ranged alongside the stage in the yard. The striking economy and convenience of this method of working is obvious, in comparison with the old method of trucking in and out by hand.

A third example of a double service conveyor is that which connects two buildings separated by a yard. It carries washed bottles in a continuous procession from the washing machines in one building and over a bridge to the filling machines in another

Fig. 269. Double Service Slat Conveyor in a Bottling Store.

building at the rate of 240 bottles per minute, or 14,400 per hour, the chain speed being 40 ft. per minute. During the journey the inverted bottles are draining, and there is always a reserve supply of clean bottles on the conveyor for the fillers to draw upon without labour or waiting.

Fig. 270 shows a double service slat conveyor for bottles, illustrating the driving gear.

It also shows one of the roller runways for the cases containing full bottles. The conveyor is arranged for labelling the bottles under way. The installation is at the

Fig. 270. Double Service Slat Conveyor and Roller Runway in a Bottling Store.

Manchester bottling store of the Cornbrook Brewery Co., Ltd., and is also the work of the Ewart Chainbelt Co., Ltd., Derby.



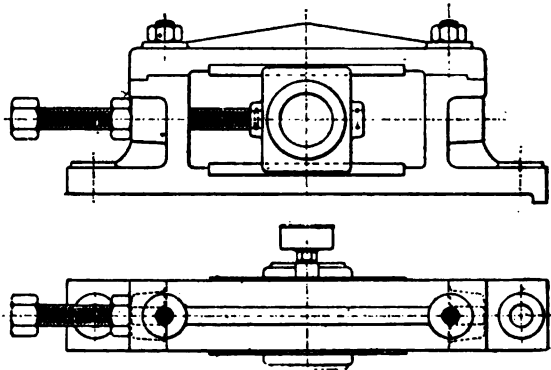
CHAPTER XVI

TIGHTENING AND EQUALISING GEARS FOR ELEVATORS AND CONVEYORS

TIGHTENING GEARS

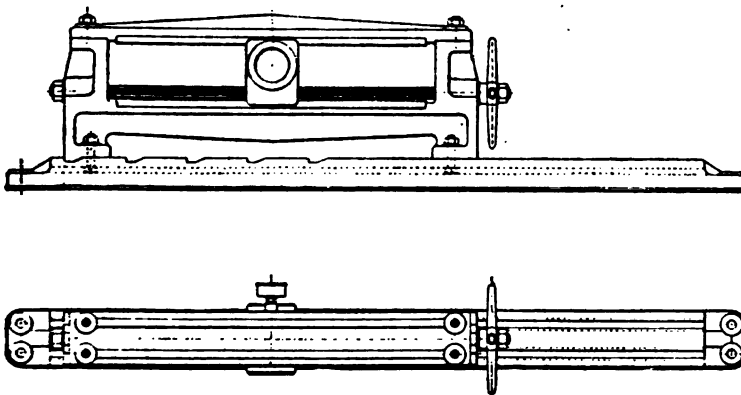
THE same sort of tightening gears can be used for a variety of elevators and conveyors. Those shown in Figs. 3 to 6, page 12, are also suitable for small conveyors, since the adjustment will not allow of great latitude.

The tension device shown in Figs. 271 and 272 is more suitable for tightening a conveyor chain or band, although as shown it allows of only a short movement. Tightening gears of the same design can be made of much greater lengths. The adjustment screw is fitted with a nut, so that the position, once adjusted, can be firmly secured. The screw can also be fitted with a hand wheel, which is often more convenient.



Figs. 271 and 272. Tightening Gear for Conveyors.

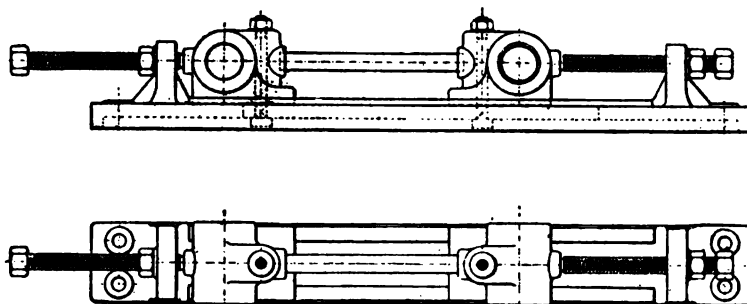
Figs. 273 and 274 show a similar tightening gear, manipulated by screws and hand wheel. This gear is particularly suitable for long conveyors where a great deal of adjustment is required, as its position can be altered on a base plate.



Figs. 273 and 274. Type of Tightening Gear for Long Adjustments.

The band or chain should always be tightened at the terminal opposite to that carrying the driving pulley, but where this is not practicable the gears shown in Figs. 275 to 278 are suitable for the driving end of elevators or conveyors in cases where

the respective machinery is driven by spur gear and countershafts. It will be seen from the illustrations that the tightening gears consist of two bearings movable in a sliding frame, the two bearings being movable together in the correct position corresponding to the radii of the spur gears, so that when the chain requires tightening both terminal

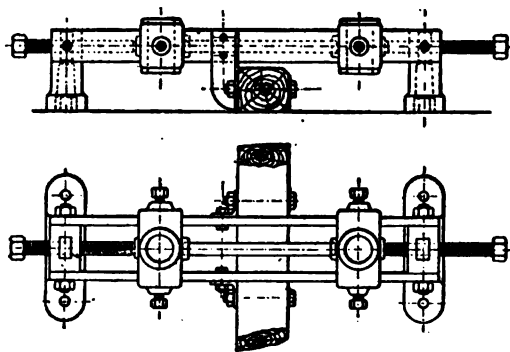


Figs. 275 and 276. Type of Tightening Gear for Conveyors with Spur Gears.

wheel and countershaft can be moved at the same time. These types are the designs of Commichau.

SPEED-EQUALISING GEARS FOR LONG-LINK CHAINS DRIVEN FROM HEXAGONAL TERMINALS

While perhaps the majority of chain conveyors and elevators are constructed of short link chains, which can be operated over round terminal wheels, it is often necessary to employ long link chains which necessitate polygonal terminal wheels or tumblers, the great detriment of which is the irregular and pulsating speed which they impart to the chain. It may be news to some that with a five-sided terminal, for instance, the velocity



Figs. 277 and 278. Another Type of Tightening Gear for Conveyors.

of the chain varies as much as 25 per cent. and 15 per cent. for a hexagonal one, as a corner or flat of the polygon passes at the point where the chain enters and leaves the terminal. Such an acceleration and retardation of the speed of the chain, *i.e.*, five or six times respectively during every revolution of the terminal wheel, is not only wasteful in power consumption, but it also imposes an unfair wear and tear upon chains and pins, and also a speed limit of, say, 100 ft. per minute. In view of this, larger chains have frequently

to be chosen. The greater the number of sides of the polygon, *i.e.*, the nearer it approaches the circle, the less will this pulsation be, and eventually it may be negligible. Such wheels with eight or more sides would necessarily be of larger diameter, and more expensive in first cost, consequently elevators or conveyors of which they form part would occupy more space.

A speed-equalising gear will remedy this defect of irregular speed and make terminals with five- or six-sided tumblers possible. In the following three such equalising gears are described :—

The Toogood Gear.—The gear, introduced by Mr H. J. Toogood, ensuring uniformity of speed for long-linked chains and hexagonal terminals, is represented in the diagram (Fig. 279).

The countershaft A is driven by belt or gearing, at a constant speed; a second countershaft B is geared to the terminal spindle c in the ratio of 1 to 6, so that B completes one revolution every time a point of the hexagonal terminal is uppermost. The two spindles A and B are geared together by wheels of equal diameter, which are bored sufficiently out

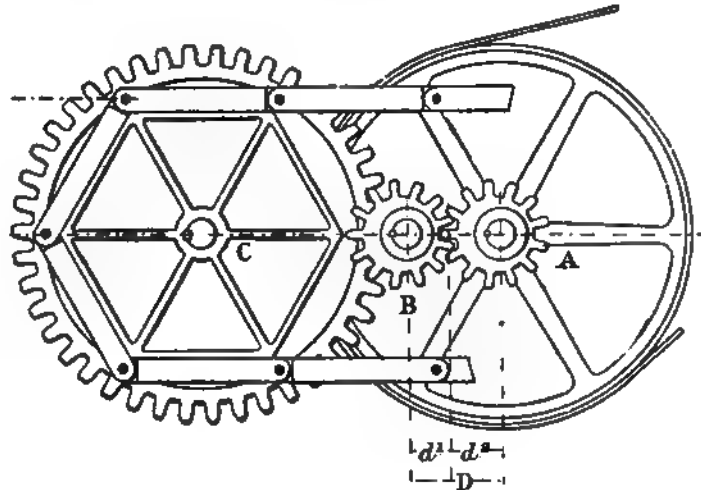


Fig. 279. Toogood Equalising Gear.

of centre to make the ratio of d^1 to d^2 vary inversely as the radius of the terminal, while D , the distance from centre to centre of the countershafts A and B, remains constant.

The Link-Belt Gear.—

Another equalising gear is that of the Link Belt Company; it consists of a wheel and one pinion only. The former has a waved or undulating circumference, and fits a circular pinion eccentrically bored, the number of elevations and depressions of the spur wheel equalling the number of teeth in the conveyor wheel. The pulsating motions of these gears exactly synchronise and counteract the variations which would otherwise affect the chain speed, eliminating all irregularities.

The Barling Gear.—

The principle of this invention consists in varying the angular velocity of the driving tumbler by the intervention of an epicyclic train operated by a cam, and is shown diagrammatically in

Fig. 280. Barling Patent Equalising Gear.

Fig. 280. The shaft A is coupled direct to the motor, and thus turns at uniform angular velocity; it carries the wheel a which through the idle wheel b gears with the wheel c . The wheel b rides loose on a pin carried on a lever c , which can be rocked about its axis

by the rotation of the cam. Imagine the shaft A held stationary. It is plain that if the arm or lever C be rocked, motion will be imparted to the shaft B through the wheel A. When the shaft A is rotating, the motion caused by the rocking arm or lever C is superposed upon the shaft B, and the cam is so cut as to compensate exactly for the shape of the tumbler. This gear is the design of I. C. Barling, M.Inst.C.E., and is built by Fraser & Chalmers.



CHAPTER XVII

CONVEYING BY GRAVITY

ALL conveying by gravity must obviously be in a more or less downward direction. Trough-shaped inclined shoots are largely used to convey material in this manner to and from mechanical devices for handling such materials. The angle at which such shoots are used depends on a variety of circumstances. If the material is not friable or likely to be injured or deteriorated in value by quickly descending the shoot on a steep gradient, and coming more or less abruptly to rest at the lower end, there is no particular need to take precautions, and the shoot can be erected to connect the receiving point with that of delivery, as long as the gradient is sufficient to ensure the descent.

When the material is friable, or deteriorates by breakage, the incline of the conveying shoot must be so chosen that the material will only just slide down, and that in so doing it cannot attain a velocity likely to injure it. These remarks refer particularly to coal,¹ and it may therefore be of interest to give a few inclines at which coal, etc., will descend a shoot in safety. The inclines are given in degrees.

TABLE GIVING THE INCLINE AT WHICH DIFFERENT MATERIALS (WHEN DRY) WILL
DESCEND BY GRAVITY IN FLAT-BASED SHEET-IRON SHOOTS.

Materials.	Degrees.	Materials.	Degrees.
Barley - - - - -	27·5	Cork, ground through $\frac{1}{2}$ -in. screen - - -	28·5
Calamine - - - - -	31·5	Furnace slag - - - - -	38
Coal, cannel - - - - -	23	Ice - - - - -	3 to 4
„ cobbles - - - - -	22·5	Limestone - - - - -	35
„ nuts - - - - -	23	Malt - - - - -	27·5
„ “run-of-mine” - - - - -	24·5	Oats - - - - -	27·5
„ slack - - - - -	28·5	Ore (average) - - - - -	36
„ „ anthracite - - - - -	31	Rice - - - - -	23·5
Concentrates (zinc blende) - - - - -	35	„ (paddy) - - - - -	24
„ „ - - - - -	30	Rock salt - - - - -	40
Coke - - - - -	28·5	Sand and gravel - - - - -	35
Concrete, wet from the mixing machine - - -	18	Wheat - - - - -	26
„ if composed of small stones		„ broken by fluted rolls - - - - -	45
which will pass through a		„ bran - - - - -	62·5
1-in. screen - - - - -	20	„ flour - - - - -	75
„ if suitable to pass through a		„ meal - - - - -	62·5
1½-in. screen - - - - -	22	„ semolina - - - - -	47·5
„ if suitable to pass through a			
2-in. screen - - - - -	24		

In tubular or semicircular troughs the material will descend at a lesser angle.

The incline of a shoot depends generally upon the coefficient of friction between the material and the shoot, and also on the form of the pieces. The incline varies from 30° to 60°, the lower figure being for such materials as washed gravel, coarse dry sand, and cement clinker from the revolving retorts, and the other extremes would be for fine

¹ For shoots from elevators, see page 26.

powders, moist sugar, salt, washed coal, etc. It will be seen from the above that a wooden shoot, for instance, would have to be steeper than an iron one. The safest plan in doubtful cases is always to rig up a short length of experimental shoot, especially if not much fall is available.

Gravity Sack Shoots.¹—If sacks have to be lowered from one floor to another, and the distance between the two terminals of the shoot is sufficiently great for a straight run, there is no difficulty in arranging such a device; but if the sacks have to be lowered perpendicularly, gravity sack shoots are the best means for handling all goods in sacks, such as flour, grain, cement, sugar, etc. Fig. 281 shows such a shoot, which is fitted inside with a number of slides or baffles which, while directing the course of the sack downwards, prevent it from attaining an excessive velocity. The sack glides from curve to curve until it reaches its destination either on a take-off table on any floor of a warehouse or to an inclined shoot leading to either rails or vessel. The take-off table is hinged, and can be closed up out of the way when not in use. This device was first brought out by Messrs Sutton, Sharp, & Hardwick, of the Imperial Flour Mills, Ellesmere Port, where it has proved thoroughly satisfactory, the gliding motion preventing any damage to sacks, which can be fed in on any of the upper floors and taken off at any lower one. The apparatus takes very little room, and is inexpensive to install. It will work equally as well with sacks of 50 lb. as with those of 280 lb.

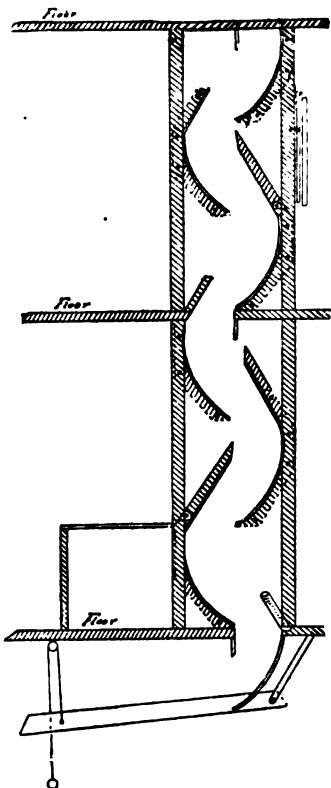


Fig. 281. Gravity Sack Shoot.

Spiral Gravity Shoot.—An ideal method of lowering sacks vertically from a higher to a lower level is the spiral sack shoot. Figs. 282 and 283 show it in two forms, the former being of cast iron and the latter of timber. The apparatus is self-supporting like a spiral staircase, and the cast-iron one in particular may be used for sacks and also for such goods as small barrels, boxes, and packages of almost every description. The diameter is 170 cm. or 5 ft. 8 in. Eight segments of the cast-iron one form one complete spiral, and the weight per foot is just about 1 cwt. The makers are Richard Simon & Sons, Ltd., of Nottingham.

A gravity shoot on the same principle as the foregoing, but for much larger packages, is shown in elevation and plan in Figs. 284 and 285. It is the first of its kind and size to be constructed, and was built by Francis Norton, Junior, & Co., of London, to convey cases from a top floor to the cellar of a London warehouse. The cases or casks are started at the top on a short length of roller runway, and vary in size up to 2 ft. 6 in. cube, and in weight up to about 4 cwt. The time taken on the journey down the shoot of course varies with the size of the case, but the maximum time does not exceed about 10 sec. On the last run of the shoot near the basement the speed of the cases is broken by several large steel spring brakes, and at the extreme end there is a plated upward incline to a small platform upon which the cases land.

¹ From *The Miller* of 4th December 1911.

Inclined Roller Runways or Gravity Conveyors.¹—The name gravity runway, though often employed for the handling devices under consideration, is apt



Fig. 282. Spiral Gravity Shoot of Cast Iron.

Fig. 283. Spiral Gravity Shoot of Timber.

to be misunderstood, owing to an overhead device similar to a mono-rail conveyor being known under this same name. It is therefore preferable to adopt the name of "gravity roller runway," or simply "roller runway." This is undeniably the simplest, least

¹ From an article written by the Author for *The Electrician*, 10th January 1919.

expensive, same time device. It be still function with dealt with scientific oldest method down an shoot in load and to permit ever-present lesser angle shoot require a gradient can be down a gradient under the

It can localities in and out warehouse at the junction is, every runways or suspended or they may with or without

For an uphill no longer a simple provide means to once more

Mod
Runway
lows:—The

Fig. 284. Spiral Gravity Shoot of Large Capacity.

cumference of the supporting rollers is smaller than the speed at which the load travels when first put on, and therefore there is not only the frictional resistance due to the rotation of the rollers to be overcome, but also that between the object to be conveyed and the rollers. This latter friction continues to come into operation until the speed of the rollers has been accelerated and has become equal to that of the load. The frictional resistance is therefore variable, and as the speed of the rollers has a direct influence upon the speed of the load, the runway is the more economical the faster it is fed, because the speed imparted to the rollers by the descending load is gradually consumed by frictional resistance during the pauses when no packages are passing. If a box is placed on the stationary rollers of a runway it will descend the incline more by sliding, due to an initial push, and this progress will continue while yet the speed of travel is so slow that the loss sustained by friction between the rollers is negligible. But as soon as the speed of the load increases it receives a further incentive by the supporting rollers, which are beginning to gain speed during the continuation of the process. In

Fig. 285. Plan of Fig. 284.

this way the first descending load sets all rollers in motion, and the following load thus finds a path ready which has already gained a small motive power, *i.e.*, it will travel quicker than the first one, and so on until the speed of the load and that of the circumferential speed of the rollers are the same and in accordance with the incline. We find frequently a slight fluctuation in the speed of the descending load, so that alternately the load gives impetus, and vice versa. This is, however, not the case when loads of uniform size and weight pass the roller path at regular intervals, when, after a little time, complete balance is established and therefore uniform speed. In the case of a miscellaneous load passing over the runway, the heavier packages will energise the rollers, and the smaller ones will be conveyed at very nearly the same speed by the energy stored in the rollers being given up to speed their progress.

The Construction of Roller Runways.—The construction of roller runways consists of a series of rollers assembled crosswise between mild steel framing of either flats or angles. The rollers which provide the path for the conveyors when in the early stages were made of hard wood, generally maple, and sometimes provided with ferrules; nowadays they are generally of cold drawn steel tubing, varying from 2 to 2½ in. diameter.

The length of these rollers varies from 12 to 24 in., thus constituting roller runways of corresponding widths. If such devices are intended for miscellaneous cargo, they are generally from 14 to 16 in. wide, even if the objects to be conveyed are wider. The rollers may be provided with ball or roller bearings, either type giving good results. While the former require somewhat less gradient, the latter are considerably more durable. The extreme lightness of conveyors of this type is one of their typical features, particularly for portable devices.

It is naturally quite possible to make these conveyors strong enough to withstand the roughest treatment, but such a course would defeat the object by decreasing their

portability and increasing their cost. As a matter of fact, at the request of the Government, a type of runway was made during the war specially light for even women and Grade III. men to handle.

Fig. 286. The Right and the Wrong Way of Placing a Shoot Case on a Runway.

The Pitch of Rollers for miscellaneous loads is sometimes 4 in. but generally 6 in. from centre to centre. If, on the other hand, an installation is intended for the same class of goods year in and year out, as may be the case in the factory where the goods are produced, say for Tate's sugar boxes, it is advisable to have the runways specially made. As it is obvious that at least two rollers must always support the load on its travel, the pitch of the rollers should therefore be a trifle less than half the length of the side of the case on which it is to travel. Some cases, as for instance those containing munitions, are provided with handles; they must therefore travel on one of the sides which has no such appendages. It is also necessary to let the cases travel in such a way that loose rope handles cannot hang down and "trap" between the rollers. As an illustration, the 18-pounder shell cases may be mentioned, which measured approximately $10\frac{1}{2} \times 10\frac{1}{2} \times 27$ in. These could not travel in the direction of their length, as would naturally be the most suitable way, owing to such rope handles; and to travel in any other way the rollers should,

Fig. 287.

by rights, be 5-in. pitch, but the ordinary 6-in. pitch runways may be used for these cases if they are placed somewhat obliquely upon them. The rollers if further apart than half the size of the cases will cause them to rock either side of the rollers and may bring them to a standstill (see Fig. 286). In such instances it is recommended that the cases be placed upon the rollers with one corner foremost, and as long as the diagonal line between two opposite corners is as long, or slightly longer, than twice the pitch, they will travel satisfactorily. A case in such a position is also shown. When the runway is used for extra long objects, such as timber scantlings, railway sleepers, corrugated iron plates, and the like, the rollers may be quite a long way apart, and expense thus saved.

For very small packages, which demand an extra small pitch, it may be necessary to reduce the diameters of the rollers in order to get them closer together. When packing cases are fitted with battens, the width of which may be 2 or 3 in., we have practically

the same problem to face as when handling cases only 2 or 3 in. long, and thus an almost continuous roller surface will be necessary. Fig. 287 illustrates a case with battens on an ordinary runway. Such a continuous surface has been produced by converting the individual rollers into a series of discs, the supporting spindles of which are pitched so close together that the discs interlace with each other, as shown in Fig. 288, in which

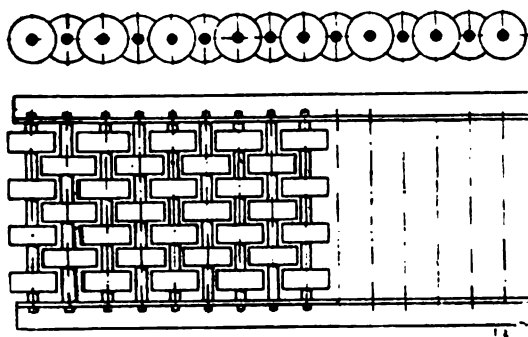


Fig. 288. Gravity Roller Path Composed of Discs of Equal Diameters.

all rollers or discs are of the same diameter. Fig. 289 shows a similar arrangement where discs of two sizes are placed alternately.

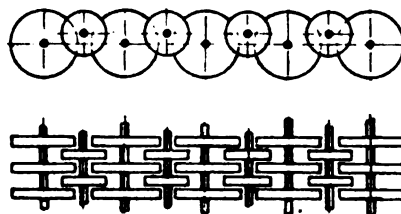


Fig. 289. Gravity Roller Path Composed of Discs of Varying Diameters.

The component parts of a roller runway, particularly if for a temporary installation, should be as portable as possible, and it has been found that by dividing them into 8-ft. lengths, or 10-ft. with wooden rollers, they are most convenient for handling by the men, and the lengths can be easily coupled together. This is also convenient for purposes of negotiating bends either in order to lay a track round a corner, or for the purpose of having an alternative track, as, for instance, when cases from a dump have to be conveyed

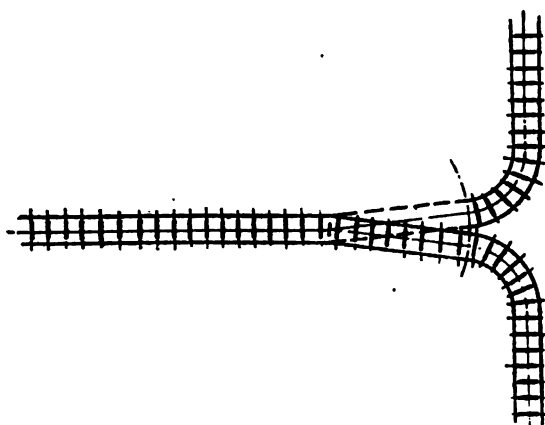


Fig. 290. Gravity Runway with Two Right-Angled Bends and a Length Used as a Switch.

out of a warehouse, and then either to the right or left for the purpose of loading railway trucks or barges. Such bends are obtainable from all the principal makers, either of a quarter turn (90°), or any other section of a circle. The rollers employed in bends should preferably be slightly conical, although light cases when travelling at a slow speed will negotiate bends with cylindrical rollers without trouble, while heavy ones at a high speed may leave the track, or at least their central position on such rollers. It is therefore customary to provide guard rails to keep them on the runway. Where truncated cone-shaped rollers are

used, the imaginary centre of the cone should be in the centre of the circle round which the bend is described. Two quarter-bends can be coupled together to form an S-bend, and by arranging two right-angled bends and a straight length as a switch, as shown in Fig. 290, the packages can be transferred to either one side or the other. Breeches pieces, as shown in Fig. 291, are also provided, but with their use it is desirable to station a man at the junction to direct the packages to either side.

Supporting trestles form an important part. When the plant is a permanent one and therefore a fixture, the segments of the conveyor are secured by simple iron or wooden brackets, trestles, or other supports from the floors, walls, or ceilings, while for portable installations a great variety of steel or wooden trestles are employed, sometimes fitted with castors. They are generally adjustable in height, as they have to be altered for nearly every scheme, since a roller runway should be erected on an even gradient throughout its length, and not form undulating curves like a switchback railway. With the use of such trestles it is desirable that one should be placed at the junction of every two lengths, that is, about every 8 or 10 ft. Sometimes packing cases may be used as

supports with packing pieces to adjust the structure to the exact height required for the gradient; or if planks are available, one 16 ft. long may support two lengths with the trestles 16 ft. apart, thus employing only half the number of trestles.

The gradient of a gravity installation varies from a minimum of 2 to 5 per cent.; the latter figure is not the maximum, but it is rarely insufficient. Heavy goods require a lesser gradient than lighter ones. The

Fig. 291. Breeches Piece.

following table is for 8-ft. units of a runway, and the amount in inches it will have to be raised at one end to produce gradients of different percentages:—

A gradient of 5 per cent. equals an elevation of $4\frac{1}{2}$ in. in one 8-ft. length.

"	4	"	"	"	$3\frac{1}{2}$	"	"
"	3	"	"	"	$2\frac{1}{2}$	"	"
"	2	"	"	"	$1\frac{1}{2}$	"	"

As the most suitable gradient varies much with the condition of the cases, it is recommended that two or three lengths of runway be set up in order to test and ascertain by actual experiment the gradient necessary before the erection of the actual lay-out for any particular class of cases. It is obvious that when there is plenty of fall available (so that there is no necessity to economise, as would be the case if a very long distance were to be covered on a small head) such tests are unnecessary, and the available gradient should be equally divided.

The condition, uniformity, and finish of cases must be taken into consideration for every lay-out. It has already been mentioned that cases are sometimes provided with battens and similar protuberances; but there are minor peculiarities as well, on cases, mostly for the purpose of strengthening them in order to be able to use the thinnest possible boards for their construction. All such devices are, if not stumbling-blocks, impediments to the smooth progress of packages on a runway, and the greater the projection of these, the greater the incline necessary for their conveyance, and consequently the shorter the distance they can be conveyed by such a gravity roller runway for a given head. The necessity for the tests mentioned under the last heading will therefore be more apparent. Not only are strips of hoop-iron, wire beading, and angle clips to be taken into account, but also the general finish of the cases. An ideal condition would be cases of well-planed boards with perfectly smooth bases upon which to travel. There

is one more consideration which particularly refers to the transfer of damaged cases; if one of these becomes stuck it means an interval of delay until it is removed. When a case is badly damaged the simplest way to handle it is to place it as a passenger upon a sound case and let it ride thereon to its destination.

A gang of "riggers" is employed when portable installations are largely used in a variety of ways for numerous purposes, as on quaysides, in railway stores, at munition dumps, etc., and such a gang should be specially trained. They set up the trestles and assemble the whole lay-out with all its switches, bends, breeches pieces, etc., and when frequent changes have to be made and where the unskilled labour for discharging cargoes is frequently changed, such a gang of "riggers" is quite indispensable for the satisfactory setting up of the track. They save considerable time, and in order to be most economical they should go in advance of the rest of the gang of labourers, so that all is rigged up ready for work under the changed conditions when the rest of the gang arrive on the scene. A good staff of "riggers," under intelligent guidance, will make provision for any possible minor change during the proceedings, such, for instance, as may occur if any warehouse or dump has to be stacked with a certain number of cases, after which the stream of goods has to be diverted to another spot. Such an eventuality should be borne in mind, and the necessary switches and branches should be in readiness at the right spot, so that at the moment the change is necessary there will be no enforced idleness of the men, and next to no break in the proceedings.

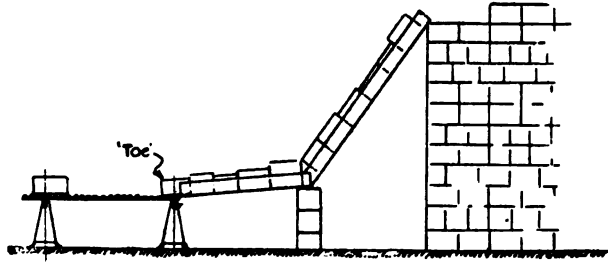


Fig. 292. Illustrating the Use of Plain Shoots.

Accessories.—Among the accessories of the roller runway the simplest is an ordinary open shoot, either of wood or iron; a spiral shoot—generally confined to stationary or permanent installations; and, most important of all, that device known as the "humper," which gives the gravity conveyor a new lease of life when the available force of gravity has been exhausted before the materials have arrived at their destinations. Another accessory, similar to the last, is the "stacker"; finally, there is the "gadget," which is employed when insufficient fall is available, in order to push the packages along.

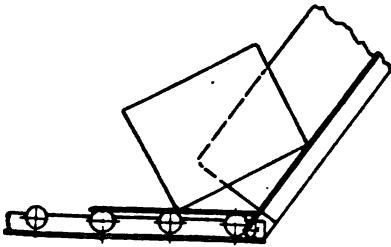


Fig. 293. Protecting Board used in connection with a Shoot.

The use of the portable shoot is only justified in short lengths, for the purpose of feeding the load to a runway from a higher level, say from the upper stratum of a stack, or from the deck of a vessel after the cases have been hoisted on deck from the hold. The employment of such shoots, useful as they are, constitutes a waste of the power of gravity. Such a waste cannot, therefore, be well afforded if conveying for a long distance on a small head. This will be apparent when it is realised that while a roller runway will transport down an incline of, say, 3 per cent., a wooden shoot requires an angle of 30°, and one of steel angles and sheets about 25° in order to convey by gravity. The utility

of such shoots will be clear from Figs. 292 and 293. If the cases descend at a fairly high speed, two shoots, as in Fig. 292, can be used, or a board should be placed on the rollers (Fig. 293) to prevent the impact from damaging them. When, owing to local conditions, the shoot has to be steeper than indicated above, a brake is employed in the shoot in order to reduce the speed of the descending load. It is obvious, as may be seen from Fig. 292, that a shoot which receives the cases from the upper regions of a stack must be much steeper than when the stack is reduced to half its height, and eventually the shoot can be dispensed with altogether. A brake in a shoot consists of a loose board or false side which can be put in and out of action by a hand lever. In the disposition of Fig. 292, where the shoot is shown full of cases, there would be no need for a brake, as the cases slide down in close proximity to each other.

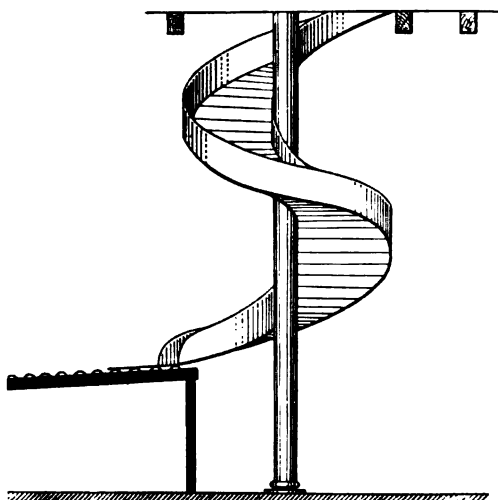


Fig. 294. Plain Spiral Shoot.

and cannot, therefore, gain a dangerous velocity; moreover, the lower and less inclined shoot provides a brake action, balancing by friction the "head" of cases in the steeper shoot.

Spiral Shoots.—With the plain shoot the material is conveyed in a more or less horizontal direction, according to the angle of the shoot; but if it is merely a question of a vertical lowering from one level to another, the helical or spiral shoot is employed, because a plain shoot at a very obtuse angle would permit the packages to descend at too great a velocity, which would be to their detriment. When strong packing cases, or bales, sacks, and barrels have to be lowered, a plain spiral shoot is employed, such as is shown in Fig. 294. When the packages require more tender handling, a spiral shoot on the same principle as a gravity runway is employed. It is obvious that the latter requires only the same gradient as a roller runway, except on a spiral path. Such a plain spiral shoot is illustrated in Fig. 295, which explains itself. If such helical or spiral shoots form an integral part of a gravity installation, they offer the incidental advantage of acting as a kind of accumulator, so that from a continuous delivery of packages an intermittent delivery may be given, and vice versa.

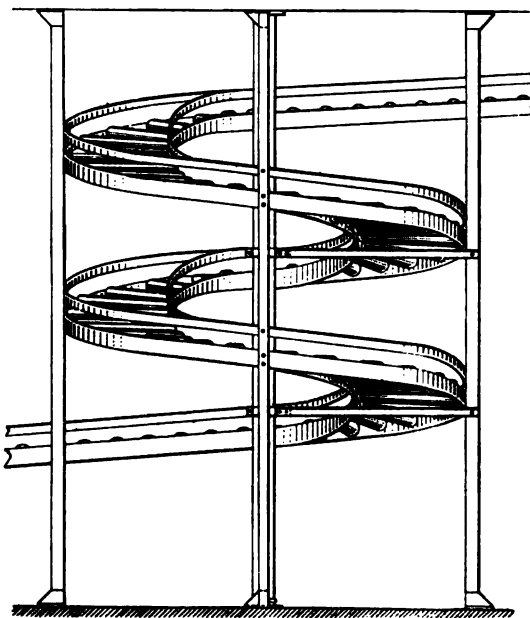


Fig. 295. Roller-Fitted Spiral Shoot.

The "Humper."—The "humper" is used when it is desired to convey for a distance longer than that obtainable by the available "head" or fall. In some cases where only a small additional head is required and for very temporary lay-outs, "humping" may be done by hand, when one or two men, according to the weight of the cases, are stationed at the junction of the two inclined roller runways, and lift every case as it comes along, from the lower end of the first conveyor to the upper end of the second one. The use of a portable mechanical "humper" is shown in Fig. 296. Such "humpers" are inserted at any convenient point of the track, and are generally inclined at an angle of 45° , with an easy curve at either terminal where the cases are gently received at the lower level and equally gently passed on at the upper end, in both cases from and on to roller runways. The "humper" provides sufficient motive power to permit the packages to travel to the end, or, as it is technically termed, "renews the gradient." Such devices may be fixtures, or portable on wheels; in either case they are generally driven by electro-motors. It may thus be seen that for relatively long distances a "humper" may be fixed about every 150 ft., so that each one has to lift the load from the lower end of the gradient to a height of 5 to 6 ft., which is sufficient to send it by gravity for the next 150 ft.

A "humper" with an angle of 45° which elevates the cases at a linear speed of 12 to 18 in. per sec., requires for a performance of handling one ton a distance of 3 ft., a maximum of 20 watt hours. This corresponds to a total efficiency of 0.13, which is approximately equal to that of an inclined belt conveyor. For a runway 300 ft. in length, with a "humper" in the centre of its length and with a difference of 5 ft. in the level between the feed and

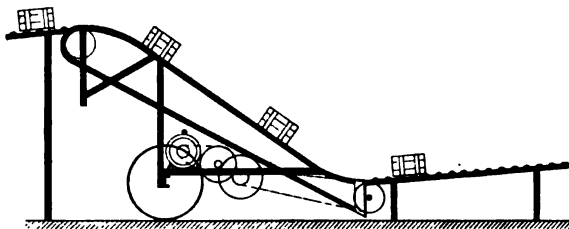


Fig. 296. Portable Mechanical "Humper" in Position between Two Lengths of Roller Runway.

delivery end, a power expenditure of $1.5 \times 20 = 30$ watt hours is therefore necessary for every ton so handled. A "humper" may also be used without the second runway for loading railway and other trucks, in which case the packages are raised by such a device from the lower terminal of a runway. A "humper," by Rownson, Drew, & Clydesdale, is shown in Figs. 297, 298, and 299, and by it the packages are carried upon a kind of apron or slat conveyor provided with claws every few feet, which successively engage with them and prevent them from running backwards. Another method is to construct the "humpers" with a roller path and two endless chains, one on either side, which are connected by cross transverses which engage with the packages, thus dragging instead of carrying them.

The "Stacker" is a machine similar to the portable "humper," but instead of "renewing the gradient" of a gravity runway it receives the cases from a roller runway and lifts them to a sufficient height and at a varying gradient to build up a stack of cases. Such stackers save an enormous amount of time in docks and warehouses. With hand labour the cases have to be raised up step by step, while the machines will do this automatically as fast as they can be fed on, either by hand or automatically from a gravity runway. Figs. 300 and 301 illustrate such a "stacker" made by Rownson, Drew, & Clydesdale, Ltd., while other makers of similar devices are the Alvey-Ferguson Co., of Manchester; the Ewart Chainbelt Co., of Derby; the Hepburn Conveyor Co., Ltd., of Wakefield; W. & C. Pantin, of London; and Spencers, Ltd., of Melksham, and others.

The "Gadget."—A "gadget" is illustrated in Figs. 302 to 304 (Rownsom, Drew, & Clydesdale's patent). This device comes into play principally when a sufficient gradient

Figs. 297, 298, and 299. Plan and Two Elevations of a Portable "Humper."



for a gravity runway is unobtainable, and where, therefore, a very slight incline, or even a level path, has to be chosen. A "gadget" may likewise be used for an uphill gradient for stacking purposes (see Fig. 305), or it may take the place of a "humper"; generally

Figs. 300 and 301. Stacket, in Plan and Two Elevations.

speaking, a "gadget" will push a steady stream of cases for about 200 ft. on a level path. This device is made 8 ft. long in order that it may replace an 8-ft. section of a runway without necessitating any rearrangement of the rest of the lay-out. The machine consists

of an angle frame which may stand on a level floor in case of a stationary installation, or may be mounted on wheels for a portable lay-out; it totally encloses the electro-motor and the propelling device. The latter consists of three endless chains which carry

Figs. 302 to 304. A Portable "Gadget" in Plan and Elevation.

three sets of roller pushers, two in a set; these emerge in turn from the enclosed box, and as they traverse the upper surface they engage and push forward every case as fed on to the "gadget," pushing them one by one on to the runway, so that each case pushes the preceding one one space forward. The cases may be fed on to the "gadget" either by an inclined shoot or by a gravity runway. It would not be practicable for the

"gadget" to push cases round the corner; the path must always be in a straight line. If angles have to be negotiated, this must be done on a gravity run after the cases leave, independently of the pushing influence of the "gadget."

Character of Load.—All individual packages with at least one plain, smooth, and hard surface can be conveyed by a roller runway; this includes cases, crates, barrels, and other containers of merchandise. There is, in addition to these, a great variety of other objects, which can equally well be thus handled by the temporary provision of a smooth, hard surface; this applies to sacks of flour, grain, and cement, coal in baskets, bundles of barbed wire, etc., all of which may be placed on trays of wood or metal. Corrugated iron sheets, railway sleepers, scantlings and similar objects may be included in the first category, requiring no special provision. It should be mentioned here that the handling of sacks and baskets incidentally on a runway is only justifiable when the runway has been put up essentially for cases, etc. If sacks and the like have to be exclusively handled, the gravity runway will not be the best method to employ, as the trays used for their support have to be returned to the head end at intervals.

Fig. 305. "Gadget" in Use as a Stacker.



Fig. 306. Shows a Man Pushing a Case on a Level Run: a method only advocated for very heavy cases.



Fig. 307. Pushing a Case by Hand up an Incline on a Roller Runway.

Applications.—The use of the roller runway is a most extensive one, principally for conveying by gravity, but also incidentally for pushing heavy loads by hand on a level path, and even uphill (see Figs. 306 and 307). The uses of the gravity runway are so vast that only a few typical examples can be given.

Examples.—The handling of piece-goods in the loading and unloading of railway trucks forms one of the most important functions of the roller runway; it is particularly applicable for these purposes, as no other handling device can be so conveniently employed for such a variety of packages differing in shape, weight, and size. It must also be borne in mind that many such piece-goods have to be handled in and out of box-trucks where a crane, telfer, or

similar overhead loading device is necessarily excluded, such trucks being only get-at-able through the side doors which easily admit gravity runways. There are few other labour-saving devices which do not depend on a perfectly straight path, and are capable of receiving their loads and giving delivery at so many different points.

If, for instance, railway trucks have to be unloaded, and the packages transferred to a place, say, 100 ft. away, at the rate of 50 tons per hour, a power-driven conveyor is often employed either as a portable or stationary device; the expenditure of power for such an appliance may be from $4\frac{1}{2}$ to $12\frac{1}{2}$ H.P., according to the type of conveyor chosen.

A gravity runway will handle the roughest cases with the available head from the floor of the truck to the ground without any expenditure of driving power, and its initial cost as well as upkeep will be considerably less.

When handling passengers' luggage the same devices are likewise very suitable. Most trunks and baskets are provided with slats of wood at the base, and must be placed on the runway so that these slats point in the direction of travel. Leather bags and sacks, etc., which have no smooth, hard surface, and are therefore unsuitable for this method of handling, are simply laid on top of trunks and baskets that are suitable, and ride thus with the crowd. The same expedient is resorted to now and again, as already mentioned, when, amongst ordinary merchandise, a broken case has to be handled amongst the cargo of similar sound cases.

The Roller Runway in Bottling Stores, etc.—Mr Atherton, of the Ewart Chainbelt Co., Ltd., Derby, quotes an interesting example in a London bottling store, where seventy lads were formerly employed in one department. They gave a good deal of trouble, and caused much waste and breakage. Three chain conveyors were

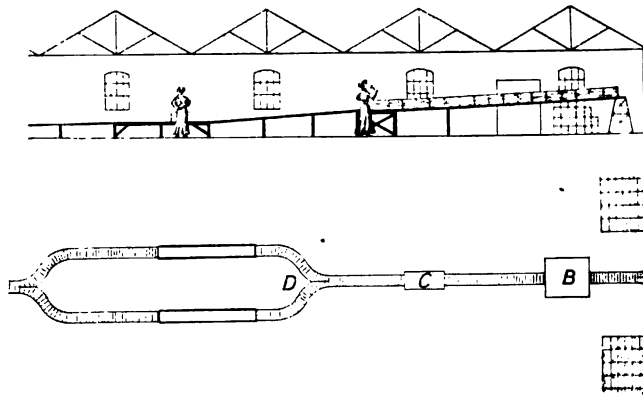


Fig. 308. Plan and Elevation of Packing Operations in a Warehouse on a Runway.

installed, and the lads dispensed with. The output on the same floor space is now doubled, the breakage greatly reduced, and thirty young girls have taken the place of the seventy lads, with a consequent saving of about £1,000 per annum in wages alone, while the cost of the conveyors was only £500. The conveyors have been running daily for twelve years, and are still doing their work satisfactorily. In Fig. 308

is illustrated, in plan and elevation, a method in which the roller runway is employed for packing purposes. The cases to be packed travel in a continuous stream to the packing room, where they are run on to packing tables at the same level as the roller path. This portion forms a double loop marked *D* on plan; it enables the packers to work on both sides, providing room for a great number of workers, and allowing more time without interfering with the continuity of the proceedings and the steady flow of cases. Whenever a case is packed it continues its journey to the next stages *C* and *B*, where it is nailed down, stenciled, and finally conveyed and stacked at *AA*, or conducted by gravity to any required point.

The combination of a roller runway with a power-driven inclined chain elevator finds frequent application in bottling factories, an example being given in Fig. 309. This shows a double strand elevator with round cross bars, which push up the boxes on a series of light steel rollers, the elevator being driven by a small electric motor. After arriving at the top, the boxes complete the remainder of their journey of 110 ft. by gravity.

In the various London establishments of the Direct Supply Co. for soda-water siphons, the cases containing the full or empty siphons are handled on roller

runways, both on the level and on the incline. Those on the level have, of course, to be pushed by hand, but as soon as they reach the incline they descend by gravity.

The cases, each of which holds twelve siphons, measure 20 in. long by 15 in. wide by 14 in. deep, and weigh three-quarters of a hundredweight each. The rollers of the runway are 9 in. pitch, 14 in. long, and $2\frac{1}{2}$ in. diameter. The spindles are fixed

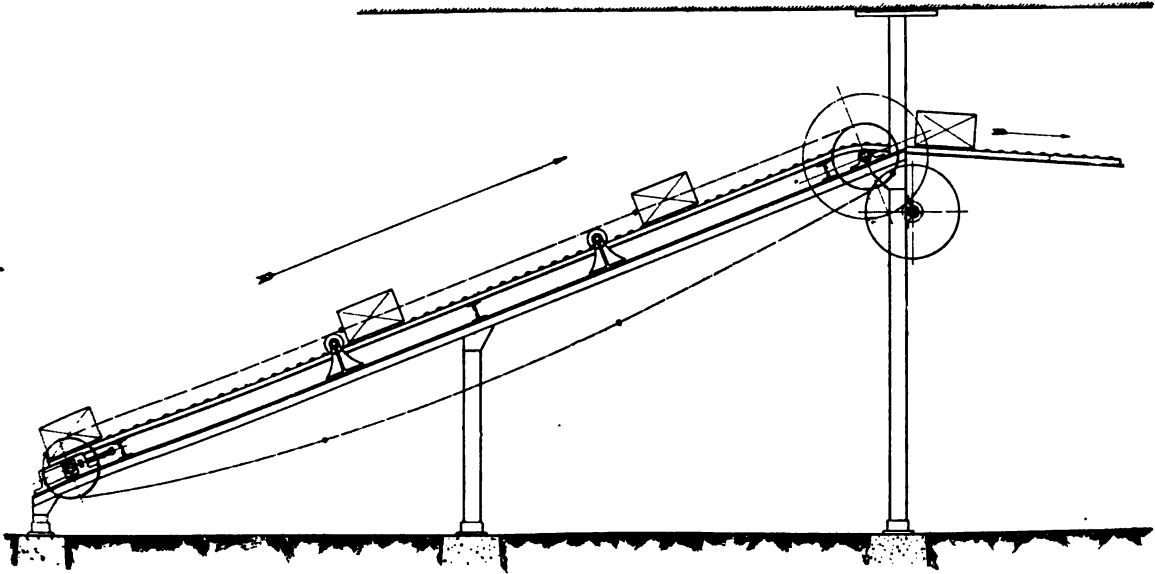


Fig. 309. Inclined Elevator for Feeding Roller Runway.

to the frame, and the rollers revolve on balls. One of the inclines is 50 ft. long, having a fall of 18 in. in its length, and the boxes run down the incline in 17 secs. Another is 120 ft. long with only 26 in. incline. This is for empty cases, and it has a curve of half a circle at the base where the cases are taken off. As this is a very slight incline, an occasional push becomes necessary.

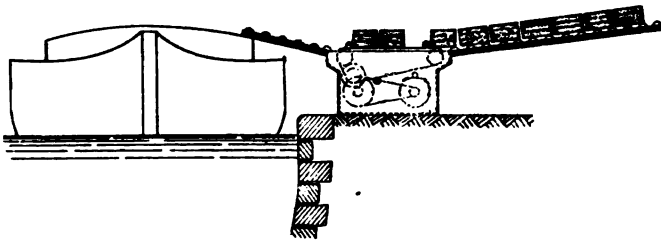
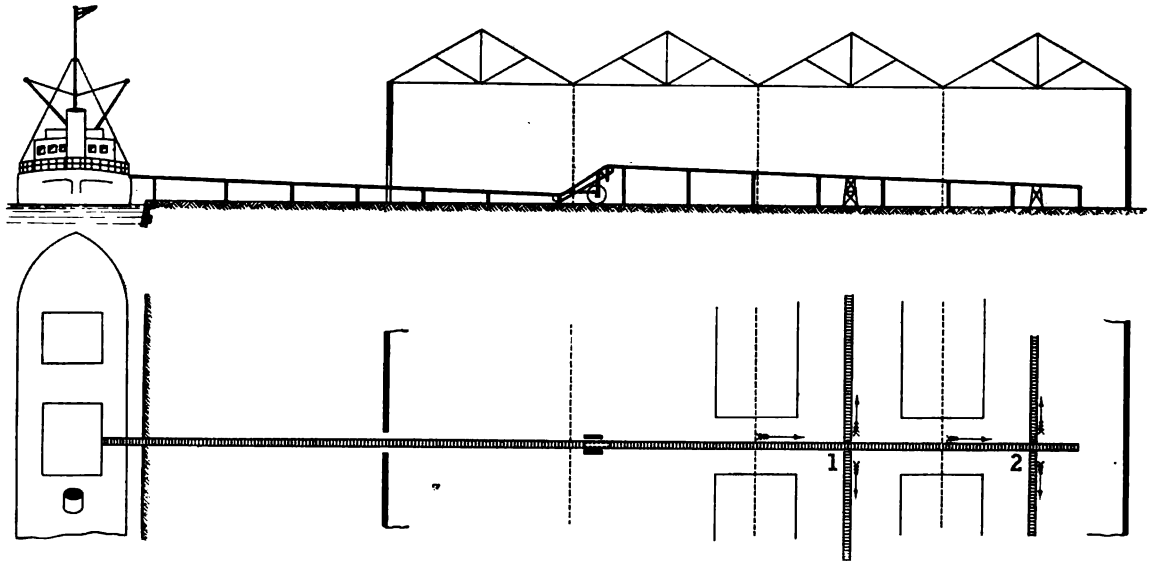


Fig. 310. "Gadget" in Use for Unloading a Barge.

An illustration of the utility of the "gadget" for a variety of purposes may be gained from Fig. 310, and shows the unloading of a barge on to the "gadget" by which the cases are pushed up an incline which may be 200 ft. long, or it may be merely long enough for the cases to arrive at a level from which they will gravitate to their destination. From Fig. 305 the utilisation of the "gadget" as a stacker will be seen.

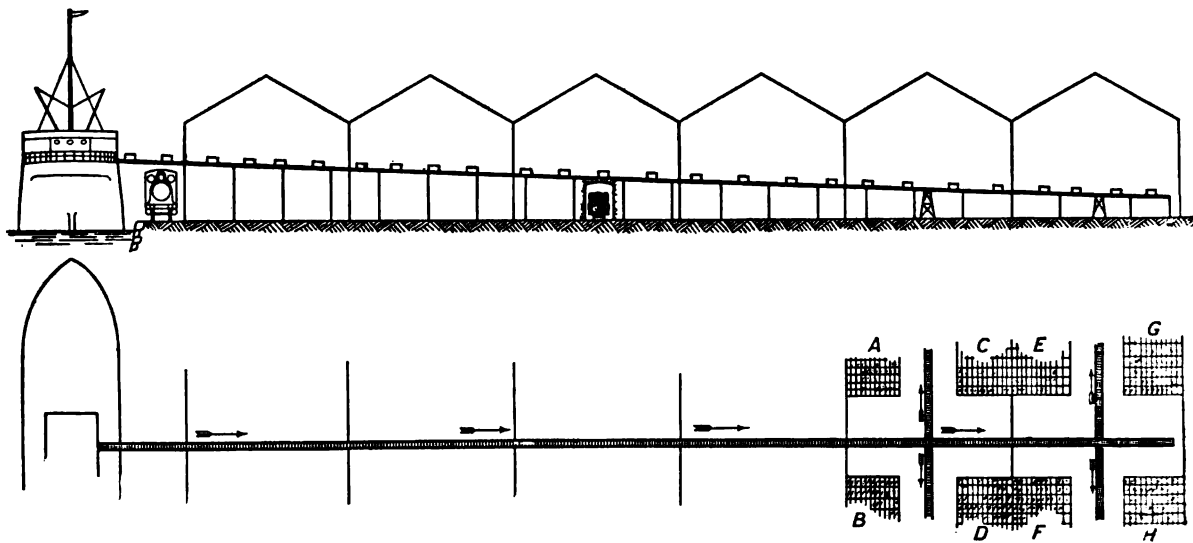
A proposition in which the miscellaneous cargo of a vessel is transferred into goods sheds, there to be stacked, will be understood from Figs. 311 and 312. Two inclined gravity runways are used in conjunction with a "humper" to renew the gradient, while four transverse runways are employed for purposes of conveying the cases by gravity to

their respective stacks (see plan). An example for a lay-out similar to the last, but entirely by gravity, will be clear from Figs. 313 and 314. Here the conveyor is



Figs. 311 and 312. Lay-out of a Runway for Unloading a Ship, in Plan and Elevation.

sufficiently high above the quay for railway traffic to pass underneath. When the packages arrive at the first cross roads, those marked A and C are turned off in one



Figs. 313 and 314. Showing the Application of Gravity Runways for Sorting and Storing Cargo, in Plan and Elevation.

direction, B and D in the other, while E, F, G, H travel on to be similarly dealt with at other points. The staff is thus enabled to sort out the cargo and deliver it on to different

stacks without manual labour or loss of gravity, the only men required being those who pick off the cases, according to their marks.

Roller Runway for the Handling of Projectiles.—A modification

of the roller runway became necessary for the handling of the vast number of projectiles which had to be dealt with to feed the guns, not only at the theatres of war, but—and there, perhaps, even more—during all the stages of their manufacture, throughout the allied countries. The use of the cylindrical form of shells naturally suggests their handling by gravity by merely letting them roll down a prepared inclined path. While abundant use has been made of this method, it is only proposed to deal here with the more complex solution of the problem, as it has been solved by the handling of projectiles by gravity runways in which suitable wheels supersede the rollers, or where the rollers are specially prepared to convey shells in the direction of their axis. The ordinary roller runway with cylindrical rollers, as has been described and as generally made, cannot be employed for handling shells as they have a tendency to roll off sideways. The provision made to keep the shells in a central position is of two kinds; in the first instance

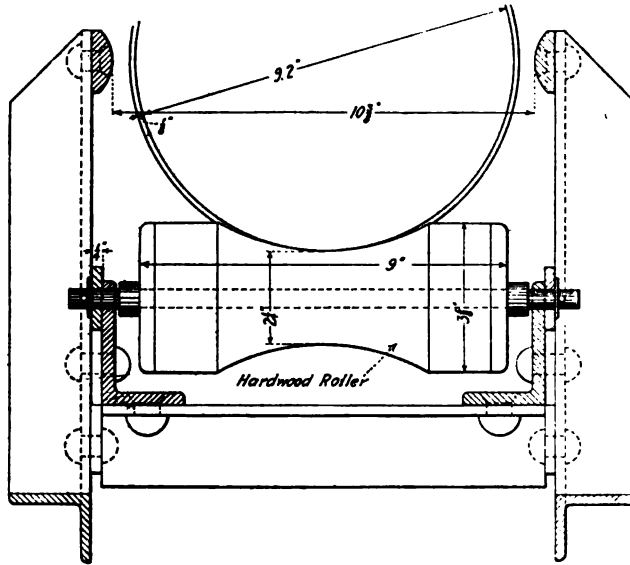


Fig. 315. Gravity Roller Runway, for 9.2 Howitzer Shells, by W. & C. Pantin, London.

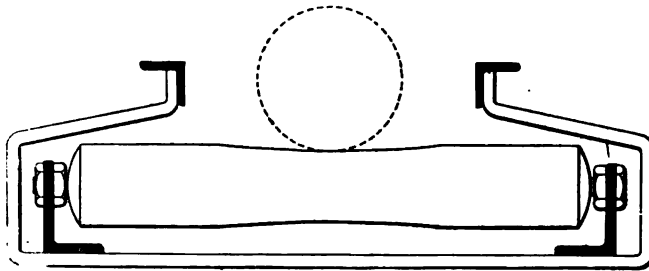


Fig. 316. Roller Runway by Alvey-Ferguson, Manchester.

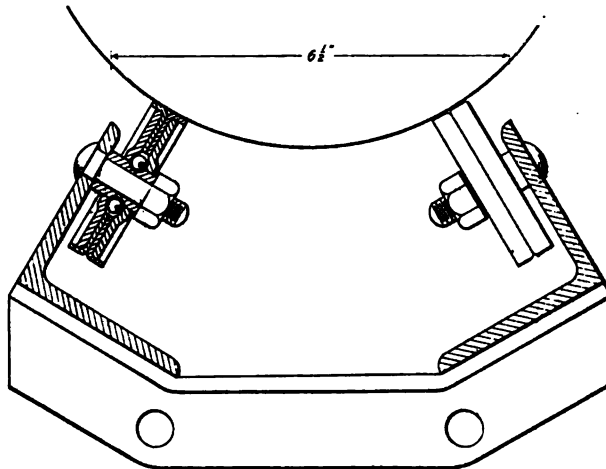


Fig. 317. Wheel Carriers for 9.2 Shells (Pantin).

the rollers are turned slightly hollow, in shape something between an hour-glass and a dumb-bell; while in the second case guard rails are provided to keep them from running off.

Illustrations, Figs. 315 and 316, show examples which combine both the conditions. Fig. 315 is the design of W. & C. Pantin, of London; it is fitted with hard wood rollers, and intended for handling 9·2-in. shells. Fig. 316 is an example of a roller runway by Alvey-Ferguson, of Manchester, and is for handling shells of various sizes.

Fig. 318. Side Elevation of "Humper" for Shells (Pantin).

Another device, for the same purpose, is the gravity wheel carrier, illustrated in Fig. 317, this example being the design of W. & C. Pantin, of London. The fundamental principle is the same as that of the roller runway, but with the application of wheels in place of the cylindrical rollers. The oblique position of the wheels naturally suggests itself to provide for snug berths for the shells on their path. For handling the rough "blanks" the bare steel wheels are employed, also for the shells in course of manufacture, while for finished shells the wheels are fitted with wooden treads. Another device for the same purpose is that of Rownson, Drew, & Clydesdale, Ltd., of London, shown in Fig. 319. This is used for shells from 6 to 9·2 in. in diameter, and for finished shells the wheels are rubber-tyred. A fall of 4 per cent. is essential when the shells travel at the rate of about 60 ft. per minute;

for banded shells a fall of 7 to 7½ per cent. is necessary on account of the obstruction to their progress by the copper bands. "Humpers" are likewise used in connection

with gravity wheel carriers and for precisely the same purposes as with roller runways, viz., to give the conveyor a new impetus. One such device is the continuous running elevator of W. & C. Pantin, London, for raising shell forgings and projectiles in all stages of manufacture, from one floor of a shop to another; this device receives the shells automatically from gravity wheel carriers at the lower terminal, and delivers them equally automatically at a higher level to another gravity conveyor. These elevators are provided with a single endless malleable chain, fitted with "claws" about 24 in. pitch, which engage with the shells while resting upon the wheel-supported path. An electro-motor of 1 H.P. will raise twelve

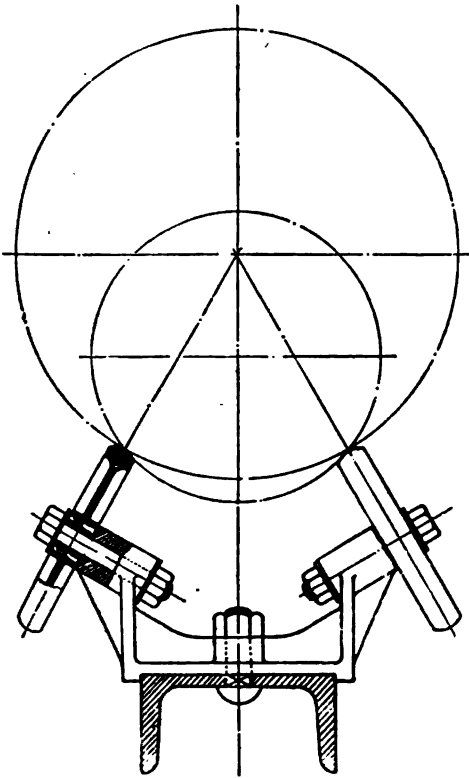


Fig. 319. Wheel Conveyor attached to Channel Girder, by Rowson, Drew, & Clydesdale, Ltd.

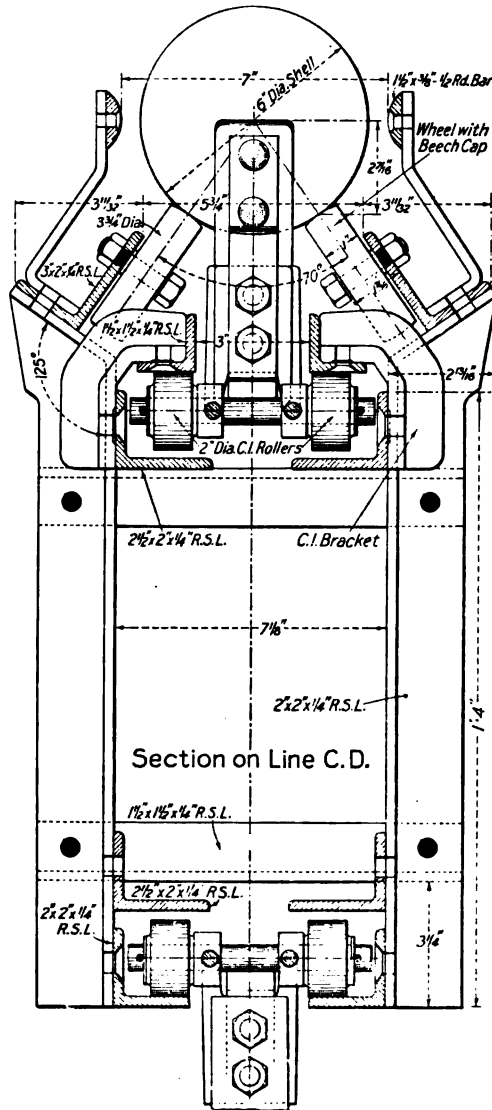


Fig. 320. Cross Section, to a Larger Scale, of "Humper" for Shells (Pantin).

6-in. shells per minute. The illustrations, Figs. 318 and 320, show two views of the elevator.

Automatic Lowerers.—A vertical swing tray elevator is often used successfully for lowering through several floors, as well as for elevating. When required for lowering only, a belt drive is convenient for regulating the rate of lowering and acting as a brake,

although the consumption of power is practically nil. Where no motor or other source of power is available, however, an automatic brake, controlled by a governor, may be fitted instead, and the lowering done entirely by gravity. The main objection is that the swing trays will seldom come to rest in the most suitable position for loading, a fault from which positively driven lowerers are free.

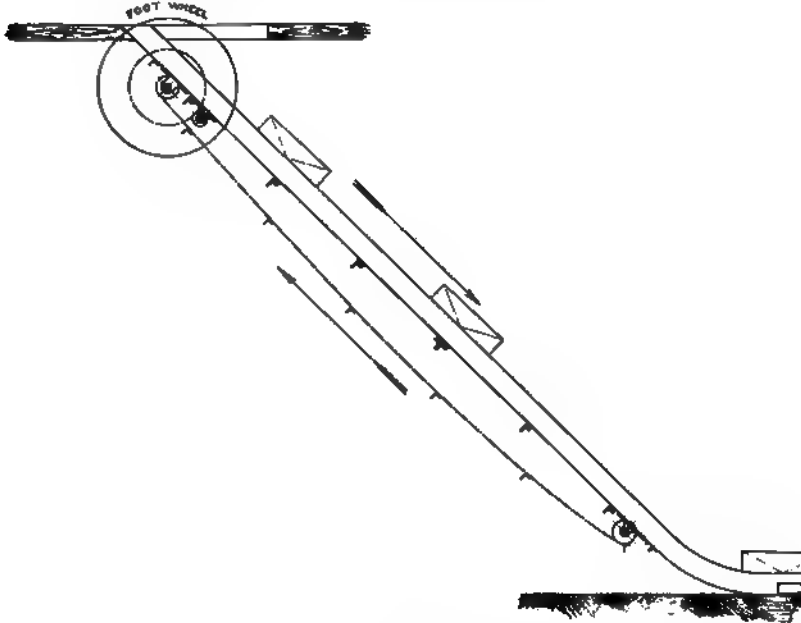


Fig. 321. Automatic Lowering Device for Packages.

Fig. 321 shows a modification of an ordinary inclined shoot, in which the rate of descent of the packages is automatically controlled by means of an endless chain, fitted with skidders, and a centrifugal governor geared to the top shaft. These inclined automatic lowerers are sometimes hinged at the top, although usually fixed.

Other examples of conveying by gravity may be found in the chapters on "Endless Chain and Rope Haulage," "Ropeways," and "Cableways."

CHAPTER XVIII

AUTOMATIC FEEDING DEVICES

C. KEMBLE BALDWIN, of Chicago, Ill., read an interesting paper on "Automatic Feeders for Handling Material in Bulk,"¹ of which the following is an extract. The illustrations of the devices are not intended to show the construction, but to illustrate the principles involved, so that they may be compared.

The automatic feeder not only saves the expense of an attendant to adjust gates, but ensures a constant and regular feed irrespective of the size of the material.

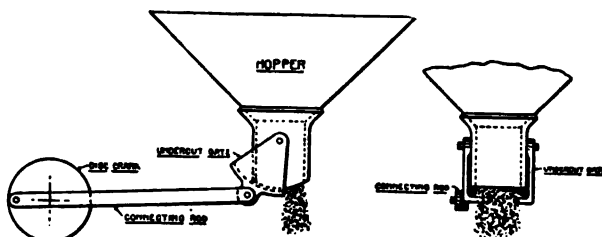


Fig. 322. Undercut-Gate Feeder.

Fig. 322 shows the undercut-gate feeder, with a body either of cast iron or steel

plate, pivoted near the top of the undercut gate, which is swung back and forth by a connecting rod from crank or eccentric. This type of feeder is best adapted to fine-sized, free-flowing material. As the feed is intermittent, the feeder is generally used in connection with chain or bucket conveyors, the strokes being timed to feed material between the flights, or into the buckets.

The capacity may be varied by changing the length or the number of strokes. As the length of stroke is more easily changed, it is preferable to use a crank rather than an eccentric, as in practice the quick return of the eccentric has not been found of sufficient value to offset the great advantages of a crank with an adjustable throw.

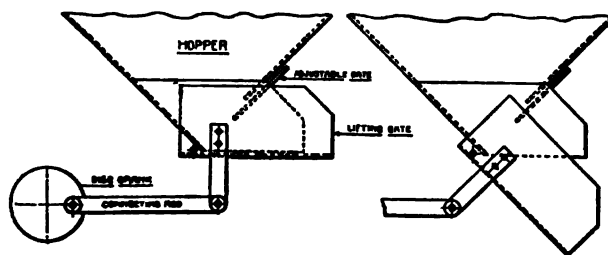


Fig. 323. Lifting-Gate Feeder.

The lifting-gate feeder, shown in Fig. 323, also gives an intermittent feed, and is therefore principally used with a chain or bucket conveyor or elevator. The shoot is hinged, so that when down, the material will flow out of the hopper, but when raised above the angle of flow of the material the discharge is stopped. The moving of the shoot may be accomplished by a connecting rod receiving motion from either crank or eccentric. This feeder will handle material regardless of size, but it must be free-flowing material, so that it will move by gravity when the shoot is lowered to the angle of flow. The capacity may be adjusted by varying the number of strokes; also, in a measure, by increasing the length of the stroke,

¹ Read before the American Society of Mechanical Engineers at the Washington Meeting, May 1909.

thus increasing the maximum angle of the shoot and causing the material to flow more quickly.

The screw-conveyor feeder, illustrated in Fig. 324, will deliver a constant stream of material, but in this case the material must be of such a nature that it will flow by gravity to the screw. The capacity can be changed only by altering the speed of the screw shaft. This type of feeder has a large field in the handling of pulverised material, such as coal, cement, etc.

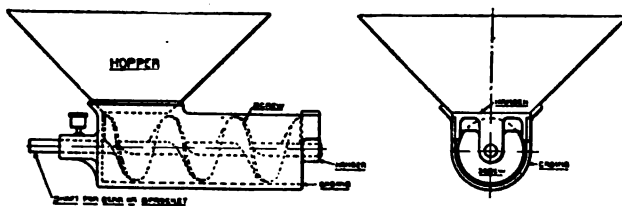


Fig. 324. Screw-Conveyor Feeder.

The roll feeder, shown in Fig. 325, is extensively used in the mineral industries for handling both large and small materials. The roll is so located under the hopper that the material will not flow when the roll is stationary, but when rotated it will carry the material forward. The capacity is determined by the speed and width of the roll, and the thickness of the stream, as fixed by the adjustable gate. The roll feeder has been successfully used in handling iron ore, coke, and stone from the bins to the weigh cars for furnace charging. Edison used this type for feeding ore and stone from bins to crushing rolls. The disadvantage is the head room required, owing to the large roll necessary to satisfactory operation. For handling mine-run material the roll should be 6 to 8 ft. in diameter, and in many cases it is not possible to obtain this space.

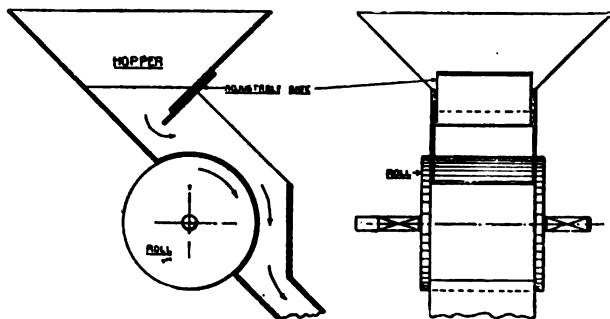


Fig. 325. Roll Feeder.

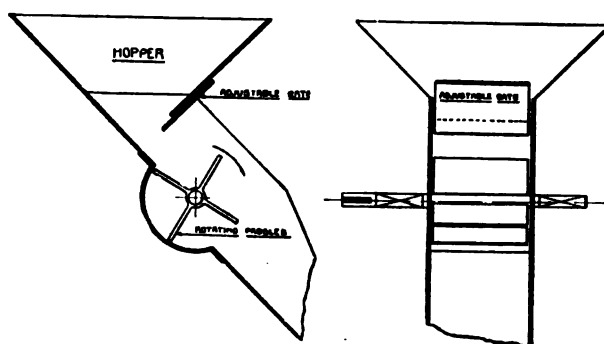


Fig. 326. Rotary-Paddle Feeder.

The rotary-paddle feeder, Fig. 326, acts not only as a feeder, but as a measuring device. It is used for fine material which flows readily from the blades. The capacity is fixed by the speed of the paddle shaft.

The revolving-plate feeder, shown in Fig. 327, is used mostly for feeding stamp-mills. The inclined plate driven by gears, placed either above (as shown) or below, moves the material out of the hopper, where it is scraped off by the skirt-board. When the skirt-board is made adjustable, sticky material may be handled by this feeder, because the curved plate will scrape the material off the

revolving disc and into the shoot. The capacity is fixed by the speed of the plate and the location of the adjustable gate.

Fig. 328 illustrates the apron-conveyor feeder used for handling material of all sizes. The conveyor may be of any of the various types of apron flights, depending upon the nature of the material to be handled. The chain should be provided with rollers or wheels travelling on track to prevent the apron from sagging. The capacity is fixed by the speed of the apron and the position of the adjustable gate. The disadvantage of this type is the inherent disadvantage of the apron conveyor. Should the flights become bent or buckled, the material leaks through or catches between them. It has an advantage over other feeders in that it may be used to carry the material a greater distance. A rubber or canvas belt may be used in place of the apron, in which case the belt is supported by idlers placed close together.

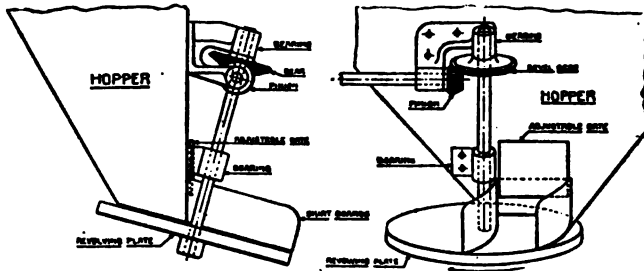


Fig. 327. Revolving-Plate Feeder.

The swinging-plate feeder, shown in Fig. 329, is used for handling coal and such material of all sizes. It consists of two castings pivoted at their tops and swung alternately so as to move the material forward on the bottom plate. The plates are moved by connecting rods from a crank or eccentric through a rocker shaft. The capacity is fixed by the length and number of the strokes, but as it is limited to the amount of material displaced by the plates, a wide range is not possible. The disadvantages are the lack of adjustability and the tendency of the material to pack. It will also be noted that the feeder is not self-cleaning, so that the bottom plate always contains material which is very liable to freeze in the winter.¹

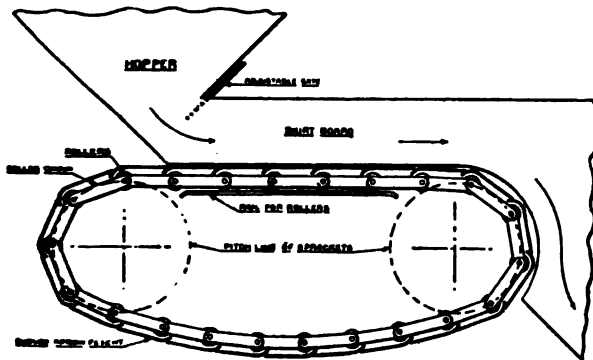


Fig. 328. Apron-Conveyor Feeder.

The plunger feeder, illustrated in Fig. 330, is similar in operation to the swinging-plate feeder in pushing the material along the bottom plate. The plunger may be built either in one or two parts, moving ahead alternately and driven through a rocker shaft, as in the case of the one previously described. The capacity is fixed by the number and length of the strokes and the location of the adjusting gate. This type has the same disadvantages as the swinging-plate feeder, the most serious being that it is not self-cleaning.

Fig. 331 shows the reciprocating-plate feeder, consisting of a plate mounted on four wheels forming the bottom of the hopper. When the plate is moved forward, it carries the material with it, and when it is moved back the plate is withdrawn

¹ This defect does not obtain in the English climate.

from under the material, allowing it to fall into the shoot. The plate is moved by a connecting rod from crank or eccentric. The capacity is determined by the length and number of the strokes and the location of the gate. The disadvantages are the lack of adjustment and the inability to clear the feeder of material.

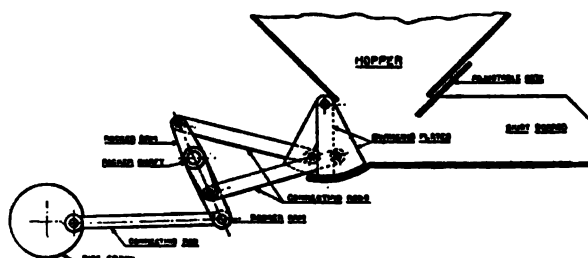


Fig. 329. Swinging-Plate Feeder.

wheels; the back end is suspended by two hanger-rods, each being provided with a turn-buckle so that the angle of the pan may be varied. The crank having an adjustable length of stroke, there may be three variables, viz., number of strokes, length of stroke, and inclination of the pan. As the number of strokes is difficult to change and the others easily changed, the feeders are usually designed for about seventy-five strokes per minute, a number determined by experiment. The angle of the pan is fixed by the capacity desired and the nature of the material handled.

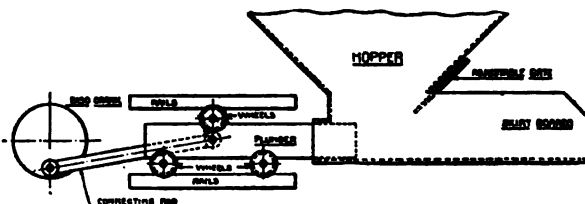


Fig. 330. Plunger Feeder.

For coal, stone, ore, etc., 8° to 10° is sufficient, while clay and other sticky substances require from 15° to 20° . The length of the stroke varies from 4 to 12 in., so that a large range is possible.

A feeder designed to handle 400 tons per hour of mine-run coal was changed in five minutes to deliver 30 tons per hour by shortening the length of the stroke and lowering the pan until nearly horizontal.

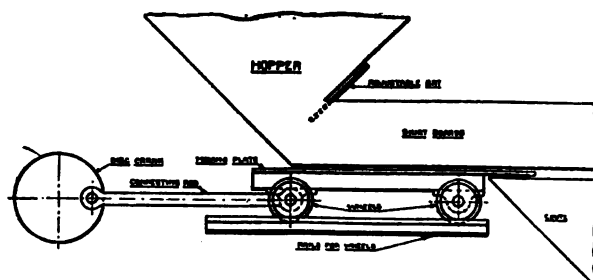


Fig. 331. Reciprocating-Plate Feeder.

the material rests directly on the pan, so that when the pan is moved the material in the hopper is moved, which prevents the material from bridging.

The shaking feeder has none of the disadvantages of the other types for general use, and possesses many advantages which the others lack. Owing to its great flexibility it is

The shaking feeder, Fig. 332, consists of the shaker-pan located under the opening in the bottom of the hopper at such an angle that the material will not flow when the pan is stationary. When given a reciprocating motion by the crank and connecting rod, the material is moved forward on the pan. The front end of the pan is carried by a pair of flanged

Not only has this feeder the widest possible range in capacity, but it is self-cleaning—a very important feature in countries where there is a severe winter. From the illustration it will be noted that the pan is placed under the opening, and

more easily standardised, and will successfully handle practically any material, regardless of size or condition. The power required by all of the types is so small that it is not an important consideration. The shaking feeder mentioned above, which handled 400 tons of coal per hour, required but 3.5 H.P.

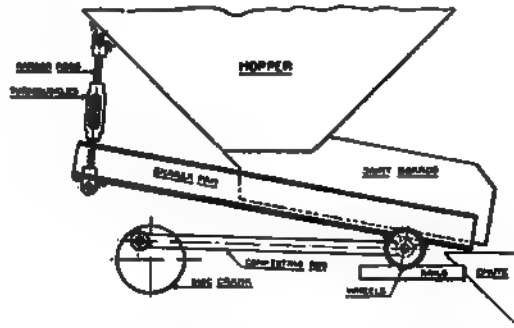


Fig. 332. Shaking Feeder.

Intermittent feeding devices for elevators and gravity bucket conveyors can be so adjusted and synchronised that the load for each bucket will be ready to be fed into the buckets as soon as they present themselves at the feeding point.

For other Feeding Devices see pages 28, 29, 116, 136.

CONTINUOUS HANDLING OF MATERIAL BY PNEUMATIC AND HYDRAULIC MEANS

CHAPTER XIX

THE HANDLING OF MATERIAL BY PNEUMATIC MEANS

By the use of pneumatic conveyors, material is carried without coming into contact with any mechanical appliances. It is, so to speak, floated in a current of air from which it

is separated at the delivery point. To ensure the material floating more or less in and with the air, it is essential that it should not be of great specific gravity, and therefore pneumatic systems of transportation are more generally used for transporting such commodities as grain, malt, seeds, and cotton, although potatoes, chemicals, cement, ashes, and even coal can also be conveyed pneumatically.

The greater the specific weight of the material, the greater must be the velocity of the air in the conveying pipes, otherwise the stock will have a tendency to separate from the air during travel, thus blocking the pipes, especially if these are horizontal, or nearly so.

Historical.¹—Passing over the earliest application of the pneumatic system for the handling of liquids, dating from 1818, also the sand blast, 1871, in which the sand is raised by means of air currents—both undoubtedly incipient applications of the modern pneumatic system—we come to the earliest method used for conveying solids, that of Edward Lord, for handling cotton, dated 18th November 1867.

One of the earliest and most important patents was that of Merrill, of Brooklyn, in 1873. A device for handling granular and powdery materials, known as the "Körting injector," was invented in 1877. It was successfully installed and actually used for elevating fine coal, flour, grain, and animal charcoal. A diagram of this device is shown in Fig. 333. In the canister A a partial vacuum is maintained by the injector B, so that the suction pipe c raises the material fed into receptacle D, similar to the action of an injector, by an air current passing through the nozzle E. The solid material which is lifted in this way into the canister A accumulates in the pipe G, until its weight is sufficient to open the valve H, which is fitted with a balance weight, and the elevated

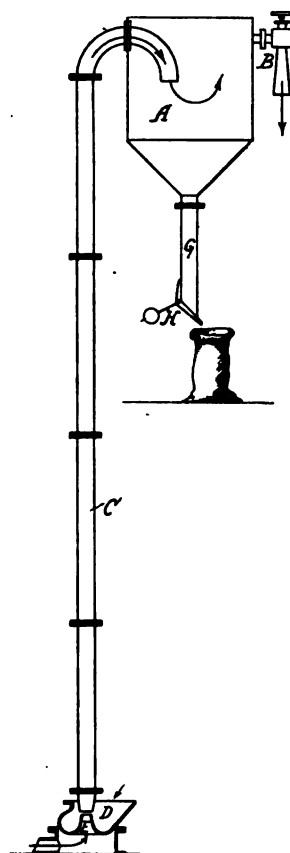


Fig. 333. The Körting Injector Type of Pneumatic Handling.

¹ The early history of "Pneumatic Handling Machinery," by the Author, see Cassier's *Engineering and Industrial Management*, 5th June 1919.

material is discharged at intervals. Owing, no doubt, to the very imperfect vacuum obtained by this method, the use of the apparatus was confined to very light materials only, and achieved therefore, like similar early appliances, but a transitory measure of success. We know now for certain that the nearer the vacuum approaches the theoretical one, the better and greater the applicability of the system for heavier materials.

Patents were taken out in America in 1879 by L. C. Renard and C. M. De La Haye; in Germany in 1880 by Jaacks and Behrns of Lubeck; in America in 1882 and 1883 by Lyman Smith; in 1884 by Frederick W. Wiesebrock of New York; and in England in 1884 by the Rev. George M. Capell of Stony Stratford; and by Oscar Bothner of Leiniz. Germanv. in 1896.

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Fig. 334. Application of Blast System of Elevating.

and erected at the works of the Compressed Air Power Co., Ltd., Birmingham, with whom the firm made arrangements for the use of their compressed air, see Fig. 334. In the course of the experiment six pipes were used for elevating maize to a hopper 40 ft. above the ground. In order to register the quantity elevated in one hour, the hopper discharged the maize into an automatic weighing machine.

Of these six pipes one was fitted up to raise 50 tons of material per hour to the bin 40 ft. above the ground; two were made to elevate each 20 tons per hour to a hopper at the same elevation; two to each carry 15 tons of grain per hour to the same height; and one to convey the grain 40 ft. in a horizontal line, and then to the hopper 40 ft. above the ground. The pipes acted as conduits, the grain being carried to its destination by the force of the air current, which, owing to the construction of the nozzle at the end

of the pipe, sucked up the grain by reason of the blast entering the conduit pipe through the nozzle.

After a series of experiments, the nozzle shown in Fig. 335 was adopted. It consists of an annular jet nozzle fitting at the entering end into the contracted throat *j* of the discharge trumpet *j'*, secured at its wide end to the first length of pipe of the grain conduits *c*. The inner nozzle *i* is screwed into a deep socket *b* and fitted with a lock nut *h* for regulating the opening of the annular jet of air issuing at *j*. The compressed air enters at *d*. The inlet end of the nozzle *i* is formed into a short trumpet *h* for leading in the grain. Of course the shape of the trumpet is altered if the nozzle is used horizontally or in an oblique position.

The next step forward, in chronological order, in the development of pneumatic conveying, was the invention of the late Frederic Eliot Duckham, in 1891. In order

to be independent of the strikes which had been prevalent during the preceding year, Mr Duckham—who was at that time chief engineer of the Millwall Docks—in 1888 decided to handle the grain at the docks by suction, a system which was, however, at that time but faintly defined in his mind. Mr F. S. Tuckett, of the East Ferry Road Engineering Works, carried out a series of experiments for him with a view to developing the pneumatic suction system of handling machinery generally, and grain in particular. These experiments were carried out at the Millwall Docks under Mr Duckham's personal supervision, and extended over a period of two years, from 1888 to 1890.

The principal difficulty was, from the first, and still is, the choice of the most suitable exhaustor for individual installations. In the first experiment a vacuum of 10 in. was obtained by a steam ejector, with which, together with a simple plant, grain could be lifted to a height of 42 ft.; but the method was discarded, owing to lack of economy. In the second instance an existing compressor engine was adapted for the purpose; the compressed air was used to blow, not suck, the grain up the pipe; to this end the grain was contained in an air-tight receptacle with a pipe leading out of it through which the air, mixed with the grain, was

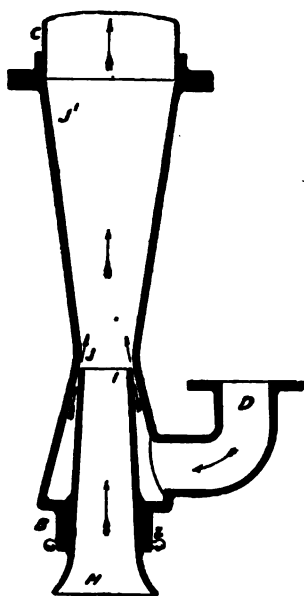


Fig. 335. Blast Nozzle of Pneumatic Elevator.

forced. This method was also workable, but lacking in economy. The third experiment was conducted with two fans erected in series; these produced a vacuum of only 4 in., and lifted the grain up to 15 or 16 ft.

The plant of the original Duckham system consisted essentially of an air-tight vacuum tank or receiver, 8 to 14 ft. in diameter, and about 10 to 20 ft. high. This tank was hopper bottomed, and erected, if floating, on a machinery barge, or if stationary in a building, at such a height that grain falling from the bottom of it, after discharging through an air-lock, could be delivered by gravity down a shoot to the grain-receiving vessel or other destination. The receiver tank is placed in communication with the exhaustor by means of a pipe.

Two or more ranges of pipes may be attached to the vacuum tank. These pipes are flexible in parts, and of sufficient length to reach to the furthest corner of the vessel to be discharged. The nozzle end of the pipe where the grain enters is of special design, to be described later on. It is generally called a nozzle. When the exhausters are started,

a partial vacuum is created within the tank or receiver, and upon the nozzle end of the suction pipe being immersed in the grain to a depth of a few inches, the air is drawn in at the orifice of the nozzle, which carries the grain up the pipe to the receiver tank.

The air, by sudden expansion from a 5 or 6 in. pipe into a large receiver tank, allows the grain to fall to the bottom of the tank and pass away through an air-lock valve, whilst the air is returned to the pumps.

A combination of suction and blast is sometimes used in the event of grain having to be collected from a variety of points to a central station and distributed again to a number of points some distance away. For such installations the best position for the compressor and exhaustor is somewhere between the two terminals, whichever may be most suitable to the locality.

The grain is sucked into a vacuum chamber, as already mentioned, and from this tank is conveyed by means of a blast of compressed air through flexible pipes to any point desired. The tank may be divided into two sections, and fitted with a system of valves in such a manner that the two sections of the tank are alternately under the influence of blast or suction, or the grain may be discharged through an automatic or other valve from the vacuum tank into a second air-tight chamber which is in communication with the compressed air chamber. This chamber is fitted with a grain-discharging pipe, and the grain is forced through it by means of the compressed air, as already described. There have been several practical applications of this latter system which appear to have given satisfaction.

Messrs Haviland & Farmer experimented with the blast system for some years, but after much experimenting with the patents taken out by Walker and others between the years 1886 and 1890, they found such inherent difficulties in the blast system of elevating as to interfere with any chance of ultimate success, and it was therefore abandoned by them. The velocity at which the grain travelled in the pipes was such as to break the grain on its reaching the bends in the pipes, and even where the berries were not actually broken, the husk was abraded, the action in the pipes being like that of a decorticator. A yet greater objection was the dust nuisance, as the grain and the accompanying air current escaped together from the delivery end of the pipes, and the air became laden with dust and fine siliceous matter to such an extent as to render it impossible for men to remain in the ship's hold for the purpose of trimming whilst the elevator was at work. This latter objection was not discovered by the patentees until a plant had been shipped and set to work on the Danube, when this proved an absolutely fatal objection to the use of the machine.

The first practical suction elevator was erected by the Millwall Dock Co., under the Duckham Patents,¹ the first of which was taken out in the year 1890, and it is under this master patent that all the existing pneumatic elevators at present in use were constructed. As the principle has already been outlined, it will now suffice to give the details of the different working parts of the invention. One of the chief items is the air trap through which the grain finds its exit from the receiver without destroying the vacuum. This is effected by an ingenious arrangement illustrated, together with the tank, in Fig. 336.

The pipes A and C are connected to the tank B, the former leading to the grain store or to the ship to be unloaded, and the latter to the exhaustor. Beneath the tank B is the apparatus which withdraws the grain from the tank automatically without destroying the partial vacuum in the same. The apparatus consists of a receptacle divided into two

¹ Duckham's pneumatic elevator and conveyor are described in *Engineering*, 29th January 1897, 14th July 1893; also in *The Engineer*, 19th February 1897 and 8th April 1898. See *Proceedings Inst. C.E.*, vol. cxxv.; see also *Proceedings Inst. Naval Architects*, 31st March 1898.

compartments H and H¹, which oscillates on its axis L, so that alternately H and H¹ will receive the grain through the aperture D. The delivery spouts K and K¹ open and close

with the same oscillating movement, so that when H¹ receives its load its exit K¹ is closed, and the inlet to H is closed whilst it discharges its load through K, which is open.

Fig. 336 shows not only the delivery of grain by suction, but also its further discharge into granaries, etc., by air pressure. Thus the apparatus is illustrated in the form in which it has been used for the combined system of blast and suction. The tank M, which receives the grain alternately through the pipes K and K¹, is connected with pipe E, which forces the compressed air into the tank, and by the use of pipe J leads the grain and air away to its destination. The grain can also be withdrawn by N. This would only be the case were the apparatus in use under suction alone. The ports G, G¹ and E, E¹ are for the purpose of establishing communication, and thus equalising the pressure between B and H, H¹ during the filling, or rather just before the filling operation takes place, and between M and H, H¹ just before the discharge begins.

In the later types the air traps in use with the Duckham pneumatic elevators, especially those for suction only, have been much simplified; their improved construction is shown in Fig. 337. The illustration shows the rocking air trap in the two positions, one in full and the other in dotted lines. The exits from the two

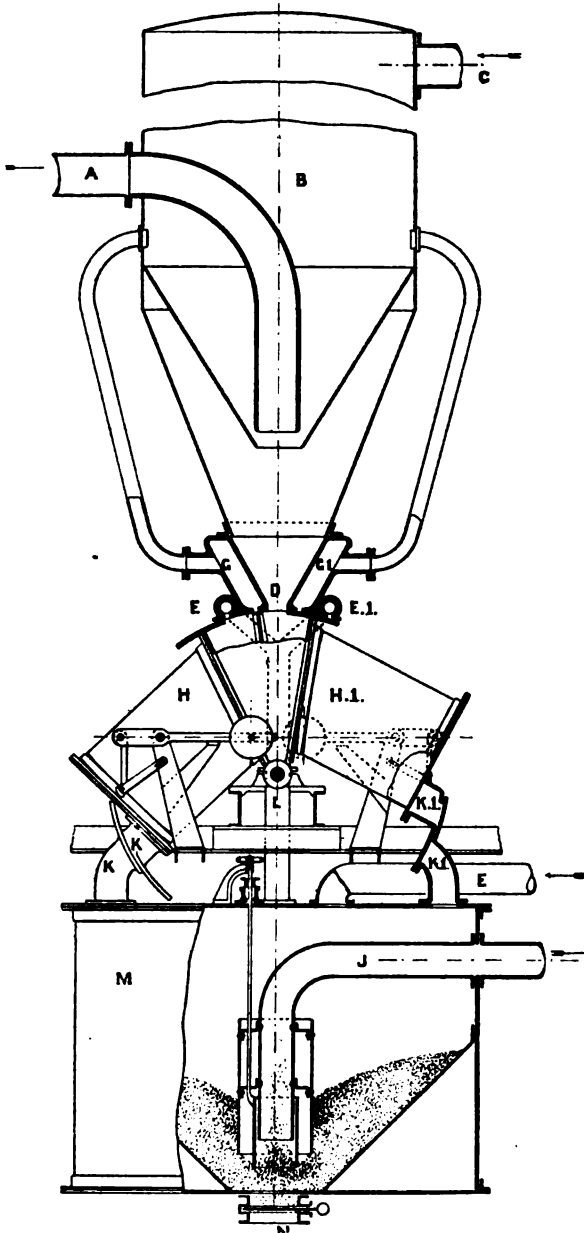


Fig. 336. Duckham's System of Pneumatic Elevating.

compartments D and D¹ are hinged flap doors with india-rubber linings. They are held closed by the outer atmosphere during loading. When one compartment is full the whole apparatus falls over to the other position, and in so doing first shuts off the inflow of grain and with it the vacuum, and then opens a port x which establishes

communication with the outer atmosphere, upon which the valve D^1 opens and allows the load to discharge. The partition between the two compartments is weighted, thus restraining the action of the apparatus until the compartment is full, when the weight of the grain overbalances it. This appliance has done excellent work, but as the air in the oscillating pockets has not been withdrawn, as in the device previously mentioned, it happens that as soon as the empty pocket is brought into communication with the vacuum chamber, the air contained in the pocket expands rapidly into the vacuum chamber and thus causes a violent disturbance to the grain in the latter. The apparatus being automatic or self-acting, requires a comparatively loose fit, and it is difficult therefore to make it anything like air-tight, and such leakage means a great waste of driving power. However, the extreme simplicity of this trap was much in its favour.

The defect just referred to has been overcome in more recent installations by providing the trap with a positive power drive and a tight fit, as shown in Fig. 338.

Stoppages of the tumbling-box, owing to sticks and straws getting between the fitting surfaces of the box and its seating, are avoided. The tumbling-box G is divided into two chambers J and H , which are alternately brought into register with the grain outlet K at the base of the canister. It will be seen from the illustration that in the position of the trap as shown, the chamber J is receiving the grain and is in communication with the vacuum in the canister, and the door L is therefore held tight by the pressure of the atmosphere. The chamber H is discharging, the vacuum having been destroyed by the port opening at the top right-hand corner beyond the casing M .

The ports N are connected with the main vacuum pipe, which produces a partial vacuum alternately in the compartments J and H prior to their communicating with the outlet K , to prevent a sudden inrush of the air from the compartments into the canister, which might disturb the normal flow of the grain. A packing strip O is provided between the two compartments of the tumbler, held by springs against the upper face of the casing M . The rest of the fitting surfaces, including the doors L , are leather faced. A crank and connecting rod P , in connection with the mechanism operated by a train of spur wheels Q , give the tumbler 10 tips per minute.

A trap of the wheel type is shown on page 246, Figs. 359 to 362, and is described on page 245.

Fig. 339 shows the construction of the suction nozzle of the early type which explains itself, the action being similar to that of an injector.

A modern suction nozzle, as made by Henry Simon, Ltd., of Manchester, is shown

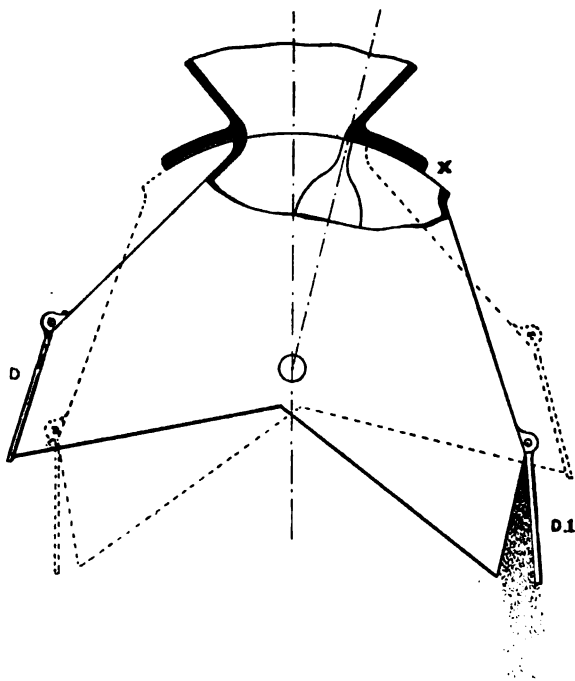


Fig. 337. Duckham's Pneumatic Air Trap.

in Fig. 340. It consists of three parts, two of which form the duct for the grain, whilst the third forms an inlet for the admittance of auxiliary air. This third section

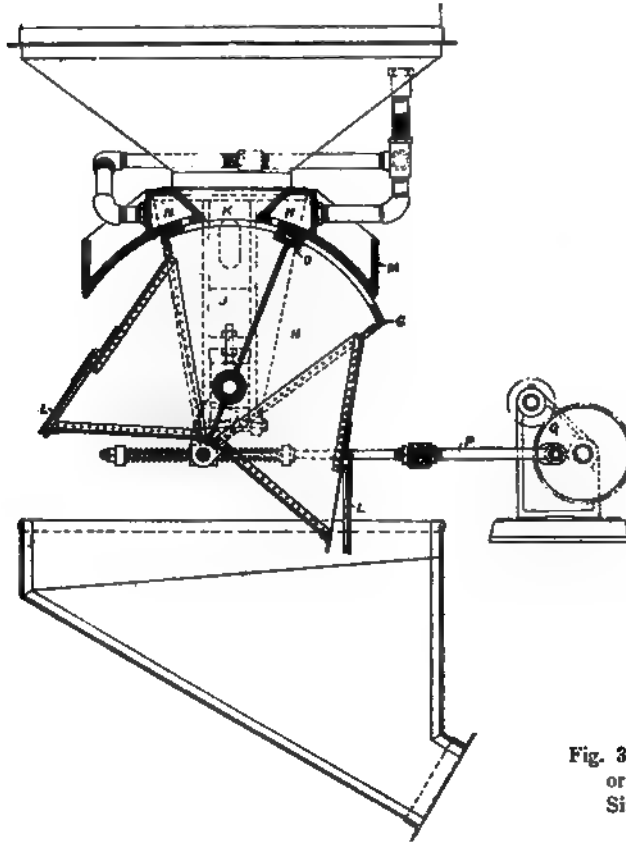


Fig. 338. Power-Driven "Tumbler" or Air Trap, as Built by Henry Simoo, Ltd., Manchester.

joins the two former pipes in such a way as to leave an annular air space. The amount of air admitted through this in excess of that entering with the grain, depends upon the nature of the grain, whether specifically light or heavy, and can be regulated by a butterfly valve.

Two continental types of suction nozzles described by Hannstengel are shown in Figs. 341 and 342. In the former the air current does not mix with the grain until after the latter has entered the suction pipe. The quantity of air is regulated by the up and down movements of the cone *x*, which alters the annular space. The openings for the grain can be regulated by the turning of the sleeve *m*. The second device, Fig. 342, is used in cases where the grain is not taken from bulk, as may be the case from a granary floor or the hold of a ship, but where it is fed from a silo. The grain enters the air current in the annular space between the outer and inner pipe, and is drawn into the suction pipe. The amount of air consumed in this type is considerably less than with the ordinary suction nozzle.

Fig. 339. Duckham's Suction Nozzle.

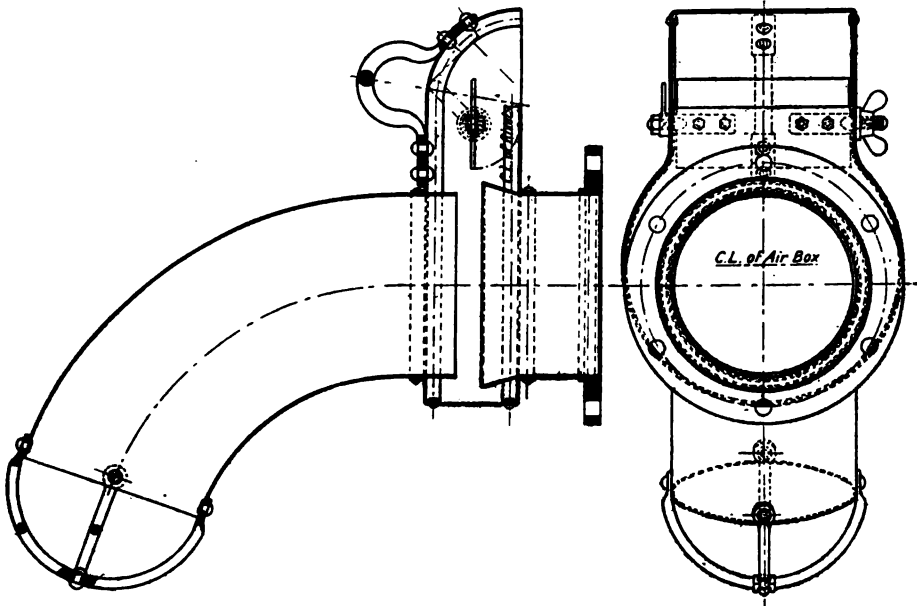
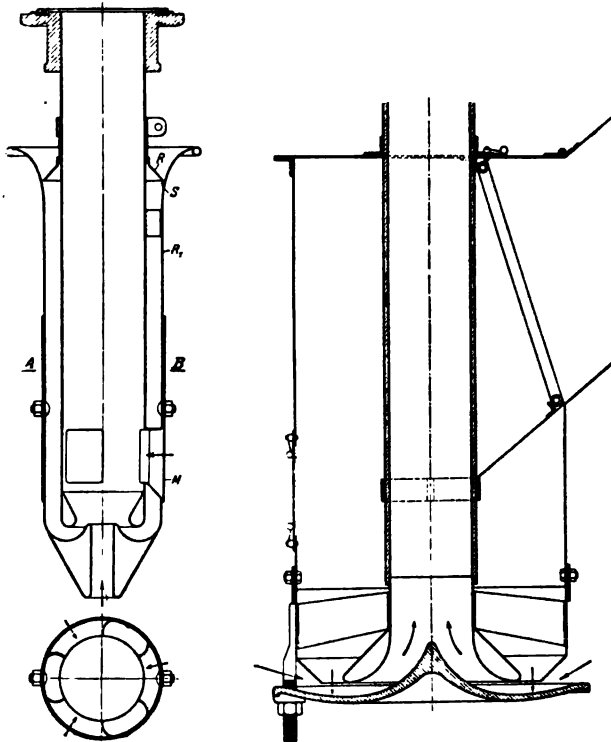


Fig. 340. Suction Nozzle, as Built by Henry Simon, Ltd., Manchester.

The suction pipe which connects the nozzle with the vacuum chamber is from 4 to 8 in. in diameter, and consists of plain wrought-iron piping for the straight lengths and flexible hose for the bends; several types are shown in Figs. 343, 344, and 345. The hose is armour-plated inside, and covered with india-rubber with insertion to keep it air-tight.

Telescopic pipes are used (see Fig. 346) for the vertical part of the pipe-line in order that the operator may be enabled to alter the height of the nozzle to the extent of 10 ft., as the level of grain in the barge may change. The upper pipe slides inside the lower one in such a way as to prevent any grain entering between the joints. The packing joint consists of a ring of soft self-lubricating



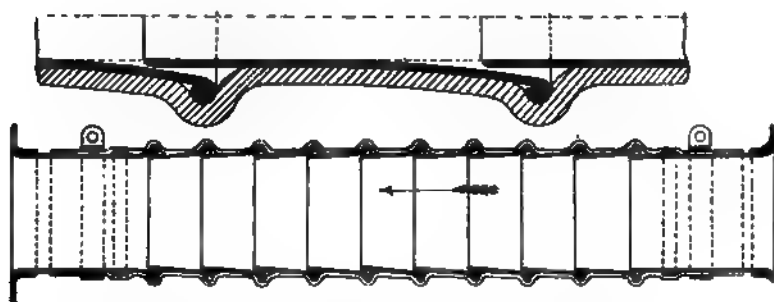
Figs. 341 and 342. Two Continental Forms of Suction Nozzle.

packing A, held in place by spring B and flange C; the packing rests upon a loose ring D, between which and the flanged end of the lower pipe is a rubber ring E. The lower portion of the pipe is raised and lowered by wire ropes over the two guide pulleys shown.

For the sake of completeness the very simple delivery nozzle which is used in connection with the blast system is here also given in Fig. 347. It consists of an iron pipe about two or three times the diameter of the supply pipe, and the length five to ten times the diameter of the latter.

The pipe which leads from tank M (Fig. 336) is connected to the delivery nozzle, and as soon as the air which carries the grain expands in the wider nozzle, the velocity of the grain is reduced, and it runs out of the pipe in a uniform stream. This method of delivery has been successfully applied in several instances, the most important being the floating elevator "Garryowen" at Limerick and the "Leitrim" at Sharpness.

The combined suction and blast system can only be used effectively in cases where the grain has been sufficiently freed from dust before delivery, or in cases where the dust would be no objection.



Figs. 343, 344, and 345. Types of Grain Suction Pipes.

With the original Duckham system a partial vacuum of 7 to 10 in. of mercury is necessary to work the conveyor. With this the grain travels in the pipe at the rate of 30 to 50 ft. per second. One pipe has then a capacity of 30 to 40 tons of grain per hour. As one of the vacuum tanks is fed by at least two pipes, the capacity of a single installation through one air trap is 50 to 60 tons per hour.

The power consumed in driving such an installation is about 3 H.P. per ton of grain to be conveyed per hour. This is exceedingly high in comparison with ordinary bucket elevators. It means that a Duckham plant with a capacity of 100 tons per hour and a 60 ft. lift would consume 300 H.P. A bucket elevator would lift the same quantity of grain with only 10 H.P. The modern pneumatic plant takes half to one-third that power, as will be seen later.

A complete installation of the Duckham elevator for discharging grain ships is shown in Figs. 348, 349, and 350. It was built by G. Luther, of Brunswick, for the Hamburg-American Line. It has a capacity of 150 tons of grain per hour, and has proved capable of very good work. A dust collector which is here employed is marked in the drawing. It is for the purification of the air before it returns to the exhausters.

the Hamburg-American Line of Steamers.

[To face page 236.]

Haviland & Farmer introduced several modifications, but since no installations on these lines (so far as the writer is aware) are now being built, they have been omitted.¹

The difference in the power consumed between the original Duckham machines built in this country and those of more modern type, is to a great extent owing to the air-pumps of the latter machines being vertical and altogether of more suitable construction than the horizontal machines which were formerly used.

POWER CONSUMPTION AND ITS ANALYSIS

An obvious advantage of the pneumatic system over a combination of ordinary elevators and conveyors is, that in unloading ships the suction pipe can be readily conducted within the hold in order to reach every corner and confined space therein; hence such appliances save the large amount of manual labour in trimming grain which is indispensable with any other unloading appliance.

The only valid objection to pneumatic elevators is the heavy initial cost of their installation and the large expenditure for fuel necessary to produce the air current. In other words, like all other pneumatic methods of power distribution, it was notoriously uneconomical; but the improvements made during the last few years have rendered the system much more economical. Formerly, pneumatic elevators and conveyors were only suitable for large installations, whereas to-day they may be employed for smaller plant also.

With the building of larger ships, the need for speedy discharge and the desire to be independent, as far as possible, of manual labour, have in the past decades been the means of introducing pneumatic elevators to a considerable extent.

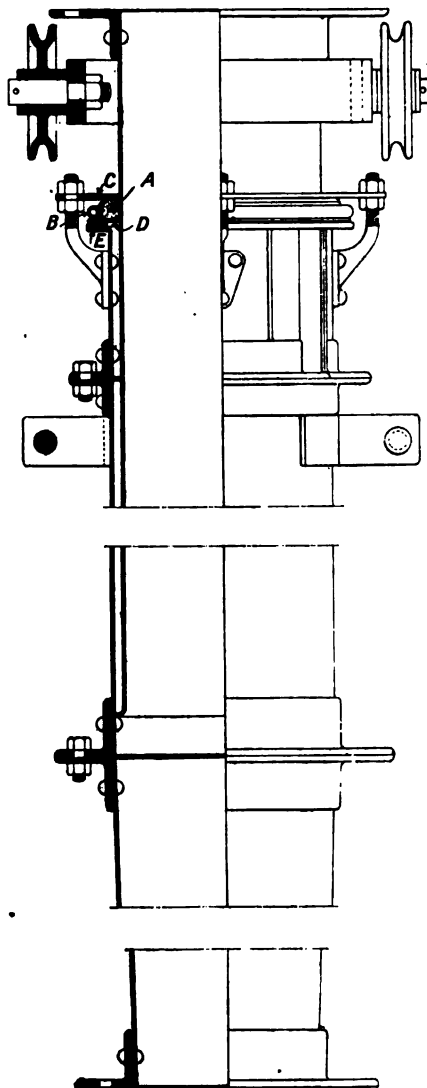


Fig. 346. Telescopic Suction Pipe, as Built by Henry Simon, Ltd., Manchester.

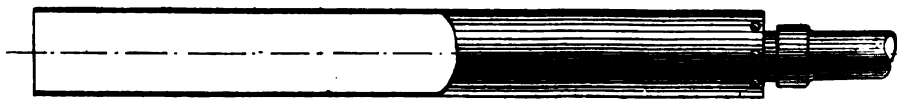


Fig. 347. Duckham's Delivery Nozzle.

¹ Such modifications are only of historical value, but full particulars can be found in the earlier editions of this work.

Although the pneumatic system is unsurpassed for the unloading of grain and is used in all grain ports, it is astonishing how little the principle, with all its intricacies, is really understood. It has been much improved in detail during the last twenty-eight years, and if our experts are able to fathom the complex underlying principles, we may expect the pneumatic conveyor to be used more extensively in other branches of industry.

A circumstance largely responsible for excessive power consumption is the utilisation of pneumatic plant for purposes for which it is not suitable, and for which other handling devices are infinitely more so.

The fact that the first installation took, under average unloading conditions, as much as 5 H.P. to handle 1 ton of grain, and that this figure has been gradually reduced to something like $1\frac{1}{2}$ H.P., shows clearly that by experimenting and by experience gained a wonderful advance has been made; but even this low

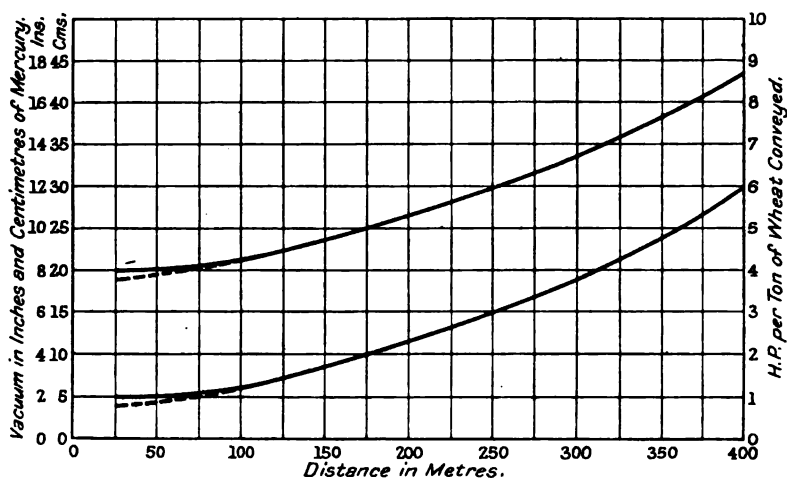


Fig. 351. Diagram showing Power Consumption of Pneumatic Grain Handling Plant.

figure, there is reason to believe, will be yet further reduced if experts continue their investigations.

The diagram given herewith (Fig. 351) is the work of Mr H. Klug.¹ The lower curve shows the most favourable expenditure of power per ton of wheat handled, for distances of from 25 to 400 metres under varying vacuums, shown in inches and centimetres of mercury at the left-hand side. This curve represents the most favourable results which have been obtained up to the present time. This data has been compiled from records of pneumatic plant collected for years by Mr Klug (including those of many makers) under all sorts of conditions. If attempts are made to work pneumatic plant with greater vacuum than shown in the diagram, the power consumption will necessarily be greater, as with larger diameter pipe-lines the average speed of the air must also be greater.

For a distance of 25 to 100 metres such plant is economical, *i.e.*, 1.2 H.P. per

¹ See article, entitled "Power Consumption of Pneumatic Grain Handling Plant," *Cassier's Engineering and Industrial Management*, 18th December 1919, by the Author, in which the diversity of power consumption under differing conditions is more fully dealt with.

ton for a conveyor for 100 metres; this rises to 2·3 for 200 metres, 3·8 for 300, and 6 H.P. for 400 metres. Up to a distance of 100 metres, plant is sometimes forced by a vacuum a trifle higher with a correspondingly high power consumption; but this does not pay for long lengths. The diagram shows alternate curves from 25 to 100 metres.

The diagram is for the handling of wheat; conditions are even more favourable for clean and polished malt, but for rye and oats they are less favourable. It would hardly pay under ordinary circumstances, as we can see from the diagram, to put in a pneumatic installation for a great length; but as it is often difficult to get way-leave from, say, a station or dock to a factory for the support of a different type of conveyor, a pipe-line underground would not be nearly so objectionable, and such a pipe would suffice for a pneumatic plant; even for a long distance this may be more economical at the high power consumption than any other handling device.

It would be incorrect to conclude that a unit of air would carry a definite quantity of grain, because a unit of air has a greatly varying carrying power, which is influenced by travelling in small or in large diameter pipes; trifling alterations of the average air speed; different vacuums; variation of temperature or percentage of moisture; varying percentage of dust. It is therefore essential to arrive by experiments or experience at the most favourable average diameter of the pipe-line and the corresponding average air speed for every class of material to be handled. The same amount of grain can be conveyed for the same distance and elevation either by a greater air volume, large pipe area and small vacuum, or by just the opposite.

Purely scientific considerations and the most elaborate calculations do not lead to reliable data for the construction of a plant, as the whole flowing and floating grain dust and air mixture under gradually increasing vacuum is likewise gradually gaining in speed in the pipes; there are, further, considerations of frictional conditions which are too complex. Our main support must therefore be empirical data.¹

The graduation of the average diameter of pipe-lines, both downward and upward to the suction nozzle and receiver respectively, must be such as to afford equal supporting power of the air current to its load of wheat in all sections. For the size of the receivers and dust collectors the tendency should be to use the smallest possible unless the filter has to be large in consideration of the pump. If the best diameter for the pipe-line and accessories has been arrived at, favourable power consumption and maximum capacity are only partly ensured, because the choice of an unsuitable pump may render the best results impossible. For piston pumps, for instance, the smaller the amount of air with each stroke and the larger the number of strokes per minute, the smaller the specific power consumption; but of course the number of revolutions of the exhaustor must be correctly tuned to the size of the suction pipes. This law is more apparent for short conveying distances and smaller vacuums, and vice versa.

Experience shows that with a displacement of 835 litres and a vacuum of 28 cm., 40 to 42 tons per hour of heavy grain can be handled for the same distance and height, while the two suction pipes of 131 mm. diameter are likewise ample provision for a capacity of 40 to 42 tons per hour. The power consumption per ton would then be:

¹ Since the above was written a valuable paper has been read by Professor Wm. Cramp before the Soc. Arts.

$\frac{53}{40} = 1.32$ H.P., a favourable result which has, however, been superseded. The use of large receivers and dust collectors in connection with single action exhausters with great stroke and small number of revolutions does not, as is sometimes believed, help to equalise injurious fluctuations and pulsations in the pipe-lines. Such large receptacles are, moreover, unsuitable for quickly overcoming any interruption.

Recent Addition to the Pneumatic Plant at the Millwall Docks.¹—This consists of a “dolphin,” elevators, and silos, together with a granary having $7\frac{1}{2}$ acres of open floor storage, situated at the north-west of the inner dock. The equipment provides for the discharging and weighing of 550 tons of grain per hour *ex* ship, and for its delivery into granary, silo, or barge. In practice about one-third goes ashore, the remaining two-thirds to craft.

The pneumatic suction plant, Figs 352 to 355, is erected on a wooden jetty 350 ft. long by 25 ft. wide, on the dock side of which the ship is moored. It is placed parallel with the quay wall at a distance of 50 ft. from it. The intervening water space which is occupied by barges is spanned by four girder bridges which connect the “dolphin” with the delivery floor of the silo on the quay. The deck of the “dolphin” is 14 ft. above Trinity high-water mark.

The sides and ends of the machine-room are built of timber, and the deck of the “dolphin” forming the roof is at this part caulked with oakum and run with pitch. The boiler and engine rooms project 10 ft. above the upper deck, and are cased in with steel plates.

There are on the “dolphin” four suction elevators, with a capacity of 75 tons per hour each. The power is supplied to these elevators by the machinery placed within the “dolphin,” consisting of a vertical compound condensing engine capable of developing 900 I.H.P. at a pressure of 130 lb. per square inch.

The power is transmitted to four pairs of exhaust pumps, *i.e.*, one pair to each elevator tower, by means of a 9-in. main shaft and helical gear wheels of steel. Hydraulic pin-couplings on the shaft admit of either the north or south section being worked independently. The pumps are double acting with cylinders 46 in. in diameter by 60 in. stroke. Each pair of pumps works in tandem, the piston rods between the cylinders and also the tail ends being supported by slippers on guide bars. The pistons are of cast iron with junk rings and $\frac{3}{4}$ -in. mica packing. The lower half circumference of each ring is of solid gun-metal of inverted T-shape with a wide flange to give greater bearing surface and reduce friction. The pump covers are of box form connecting with suction and delivery air-pipes, the air being drawn through the ports on the top half of the grid-plates, and discharged through those on the bottom. The normal speed of the pumps is 40 revs. per minute.

On each elevator tower there is a vacuum chamber or grain receiver 20 ft. high and 14 ft. in diameter constructed of steel plates with internal angles and baffle fittings. The vacuum maintained in these chambers by the pumps is usually from 7 to 10 in. of mercury, but varying with different classes of grain; the denser the grain the more complete is the vacuum required.

Each receiver or “canister” has two valve branches for the connection of grain suction pipes, and is coned at the lower end in the usual way and connected to automatic

¹ Extract from a paper, entitled “Some Recent Grain Handling and Storing Appliances at the Millwall Docks,” read by Magnus Mowat before the Inst. Civil Engineers on 2nd March 1909.

oscillating air-locks or "tippers" of the Duckham type, which are of 5 bushels capacity and discharge about nine times per minute.

PLAN OF AIR - EXHAUSTER PUMP - ROOM
 SECTIONAL ELEVATION
 AND PLAN OF TOWER
 Figs. 352 to 355. Latest Pneumatic Grain-Handling Plant at the Millwall Docks.

The grain is sucked from the ship's hold to the "canister" to a height of say 80 ft. through "Armadillo" pipes varying in diameter from 6 in. at the receiving end to 10 in.

at the "canister." These pipes are made of conical steel plate rings 6 in. long overlapping each other, the whole being taped together with flax webbing and encased in a jacket made of leather, or of canvas impregnated with rubber. The pipe is made up in lengths of 10 ft., which are coupled together with bolt couplings having internal rubber washers to keep them air-tight. Steel taper pieces are used to reduce the diameter to 6 in. at the lower end where connection is made with the nozzles. The steel rings resist the wear by friction of the grain and the enveloping hose makes the joints of the cones air-tight. The pipe is supported by chains slung from derricks and is so flexible that a 10-foot length may be bent to a quarter circle.

The nozzles are of steel of 6 in. internal diameter and about 2 ft. long; the adjustable sleeve outside allows an air space of 1 in. all round. This sleeve must be adjusted to give the necessary supply of air. This is a most important factor, as the vacuum obtainable is directly controlled thereby. The range of the sleeve may be taken as 2 in. for extreme positions. With good oats it may be raised an inch and a half above the nozzle but with sluggish wheat it will have to be brought down half an inch below it. By lowering the sleeve more air is admitted; this is required for higher lifts or when the pipes are much curved for getting under the coamings. There are two varieties of nozzle used, "straight" and "camel back," the latter type being kept for working under coamings or in places inaccessible to the straight nozzle.

From the canister, where the air and grain are separated, the latter passes through the tipper into a weighing hopper, where it is drawn off by means of a slide valve into the weighing machine. That portion of grain intended for shore goes through weighing machines and thence by hopper to a band conveyor on the bridge spanning the 50 ft. to the quay. The remainder is weighed and passed direct into craft alongside through steel spouts, being either sacked on platforms, slung from the "dolphin," or it may be moved in bulk.

Before finding its way to the atmosphere the exhaust air from the pumps is passed through a "stive-room" or settling chamber of 3,000 cub. ft. capacity; these stive-rooms form the lower part of the towers. Here any dust which may have passed through the pumps impinges on baffle plates, is collected by a mechanical scraper gear, and is led eventually to the canister through a by-pass, being again incorporated with the grain to maintain its weight.

There are two floating elevators with a collective output of 250 tons per hour. The machinery is of the type already described, but is placed on floating steel tanks or barges, which are capable of being navigated in the dock. The larger vessel known as "Mark Lane No. 3" has two towers and is 90 ft. long, a smaller "Mark Lane No. 2" has one tower and is 65 ft. long, the beam in each case being 24 ft., and the draught 10 ft. The discharge is direct to barge only, from which the grain, if required for housing, is transferred to the travelling bins by means of grabs.

What appears to be an important feature in this new installation at the Millwall Docks is the tapering pipes. Mr Magnus Mowat, M.Inst.C.E., has carried out a series of experiments to determine the efficiency of these tapering pipes as compared with the 6-in. cylindrical pipes of the earlier plants, and the tests have shown that on the same receiver two of the taper pipes dealt with more grain than three of the 6-in. cylindrical pipes working under similar conditions. He also found that the velocity of the air in the pipes is approximately 100 to 150 ft. per second, and that the mixture of grain and air might be averaged at 1 to 50.

Although the latest installation at the Millwall Docks provides 3 I.H.P. per ton of grain lifted, Mr Magnus Mowat states that actually only 2.5 H.P. is required per ton per

hour. At the Surrey Commercial Dock, in a similar pneumatic installation, 2.16 I.H.P. was consumed per ton per hour. The lift in this case is 12 ft. less than at Millwall, and the cylinders of the air-pumps are water-jacketed.

In comparing the power consumed by pneumatic elevators, it must be borne in mind that in some cases of unloading there are 80 ft. of vertical and 100 ft. of horizontal pipes, which means conveying for some considerable distance, and entails consequent expenditure of power.

Mr F. S. Tuckett states that with the last machine built on the Duckham system at the East Ferry Road Engineering Co.'s Works, working under ordinary conditions with steamer cargoes of 3,000 to 4,000 tons of bulk grain, an average quantity of 197 tons per hour can be removed with a crew of seventeen men and an engine-room staff of five, whose total wages amounted to £1. 6s. 8d. per hour. The coal consumption is 4.75 lb. for every ton of grain lifted. Allowing for coal at £1 per ton, and for stores at $\frac{1}{8}$ th of a penny per ton of grain lifted, the cost of unloading these cargoes amounts to 2 $\frac{1}{4}$ d. per ton of grain.¹

Mitchell's Improved Pneumatic Elevator.—Mr A. H. Mitchell, for many years engineer to the late London Grain Elevator Co., and now on the engineering staff of their successors, the Port of London Authority, has had unique opportunities for experimenting with and investigating practically every known system of grain handling by pneumatic means. He has diagnosed the reason of the failures of some, and followed up or further developed the latent good points in others, and he is undoubtedly one of the best authorities of the day on this subject. The writer is indebted to him for a number of interesting interviews, and the following description of the latest developments introduced by him on this important method of grain handling is the outcome of these interviews.

In the original elevators a tendency was discovered for the speed of the grain in the pipes to accelerate, during the whole of its journey, and thus enter the "canister" at an extremely high velocity. To rectify this obvious fundamental defect, the diameter of the pipes was increased as they approached the "canister" in order to reduce gradually the velocity of the air. This idea was developed on the lines that if the pipes receiving the grain from the hold were kept practically vertical, the initial velocity in the lower portion of the pipe would be sufficient to carry the grain a very considerable height without the further expenditure of energy. The existing machine was altered, therefore, in such a way that the expanded pipes were carried far down into the hold of the ship, and the upper end was joined to a more or less sharp bend of considerably enlarged cross section, and from here the pipe was conducted at a downward gradient to the "canister." This down pipe is of a diameter sufficiently large to reduce the speed of the air current as the grain slides down by gravity. As a further development the large vertical pipe below the bend was made telescopic,² so that without the addition of more pipe the grain could be lowered down in the hold. This utilisation of the kinetic energy in the grain has led to a considerable decrease in the amount of power required.

A typical example of a plant on these lines, built by Henry Simon, Ltd., of Manchester, is shown in diagram Fig. 356, which represents a floating pneumatic elevator with a capacity of about 200 tons per hour. It will be seen that the pipes are not only telescopic but that the inclined down pipe forms a boom which can be slewed sideways, and at the same time luffed vertically.

The plant is mounted on a steel pontoon. The suction pipes are of small diameter

¹ These figures, given in 1909, naturally do not apply to present coal and labour prices.

² See reference to telescopic pipe on illustration, Fig. 346.

at the intake end, considerable initial velocity being thus imparted to the grain, and this velocity is made use of to complete the travel of the grain to its highest point at the bend c. The diameter of the pipe gradually increases from the lower length to the bend. After the bend the pipes incline downwards to the receiver *ε*, and this part of the transportation being thus largely effected by gravity, a saving in power is consequently obtained. The pipe boom is connected to the receiver through a socket joint and turntable *δ*, which enables the boom to be luffed through an angle of 30°. At the same time the boom and the whole structure carrying the electric winches *κ*, and control cabin *γ*, can be slewed through more than half a circle, enabling a grain ship to be worked on either side, end on, or broadside on. The grain is distributed among six automatic weighers and delivered through flexible spouts *μ* to lighters on either side of the pontoon, to the sacking-off platform *ν*, or ashore by means of band conveyors and shoots.

Owing to the elevated position of the "canister" in the original elevators they became rather top heavy, but the development of the down pipe idea has now led to an entirely new type of machine. The grain in the first place runs into quite a small receiving chamber *ε*, which is placed low down on the deck of the pontoon, thus removing at once the enormous amount of top weight and every possibility of capsizing. The grain is discharged from this "canister" into the well of a bucket elevator *ι*, and the power required to drive this is saved many times over in the economy effected through the expanded pipes. This arrangement permits of a higher weighhouse which, instead of having a divided grain hopper, as formerly, which may give a list to the machine, has only one central hopper of about half the size of that required with the old type, and cannot produce any alteration in the trim of the pontoon.

To provide for the various widths as well as heights of steamers, the pipe booms are arranged to form a crane, and can be raised, lowered, or luffed, whilst the "canister" becomes the kingpost of the crane upon which the whole can revolve, so that the pipe can instantly be swung to port or starboard, or otherwise adapted to meet the requirements of the hold.

A further improvement is effected by placing a substructure upon which the crane stands out of the centre line of the pontoon, whereby it is possible to adapt the pipes quite readily to ships varying from 40 to 90 ft. beam, since they will have a much greater reach over one side of the pontoon than over the other, whilst the reach over the end is arranged to be half way between the two.

In order to avoid the enormous "stand-by" losses involved by the use of boilers, oil engines are introduced instead of steam, and these are geared to turbo-exhausters of the compound type instead of pumps, thus doing away with all valves and piston leakages.

The grain is extracted from the receiver or "canister" *ε* by a tipper of the Duckham type, which has been found after many years' experience to be the most reliable and satisfactory method of extracting the grain. It differs from its predecessors in so far that the sides, ends, and rubbing surfaces are packed to avoid leakage, and for the old system of gravitation tipping a mechanical backward and forward motion, so many times a minute, is substituted (see Fig. 338).

The rotary wheel trap or seal appears at first sight to be more scientific, but owing to the shallow depth of the pockets, even with a trap 3 ft. in diameter, their tapered form and the enormous number of blades passing per minute, they were extremely liable to break down caused by foreign matter in the grain. It will be seen that owing to the tapered form of the pockets when half full, according to their bulk capacity, they are more than three parts full by vertical measurement. This brings the top surface of the

Fig. 356. Floating Pneumatic E

- | | |
|--|-----------------------------------|
| A Flexible pipes. Additional sections can be inserted. | G Driver's cabin. |
| B Patent telescopic pipes, giving variation in length of 15 ft. | H Electric winches. |
| C Bends. | J Elevator feeding weigh- |
| D Socket joint and turntable. | K Weigh-house. |
| E Grain receiver. | L Automatic grain weigher. |
| F Tumbling-box seal. | M Flexible spouts. |

grain, and with it the foreign matter, very near to the top of the blades. A mechanically operated tipper, owing to its slow movement and its much greater depth of receiver, whilst giving the advantages of the rotary seal, entirely overcomes its defects. (This view is not shared by all experts.)

A similar type of elevator, but mounted on wheels and a rail track on the quay, is shown in Fig. 357. In this case the inclined pipes will be seen leading into a "canister" from which the grain is discharged into a bucket elevator, and raised into a weighing machine, then re-elevated for delivery into pockets in the warehouse wall. This installation was also built by Henry Simon, Ltd.

Small Pneumatic Grain Elevators.—Installations of small capacities have recently been introduced, particularly for the use of millers, maltsters, oil-mills, and the

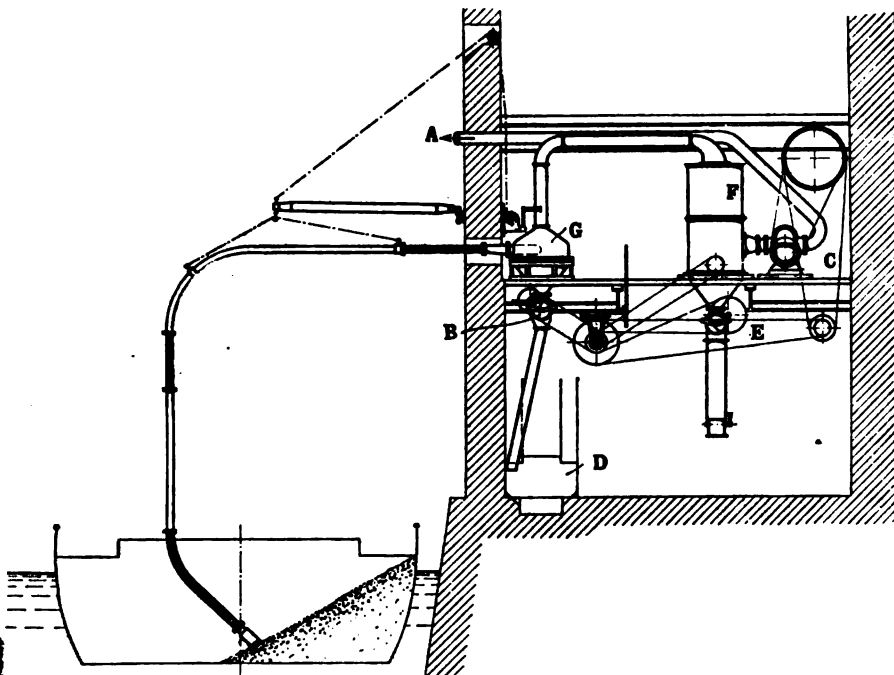


Fig. 358. Pneumatic Grain Elevator at Messrs Leatham & Sons' Flour Mills, York.

The one here described is that at Messrs Leatham & Sons' Flour Mills, York. 358 shows the whole installation in diagrammatic form. As these small plants are similar to the large ones already fully described, it will suffice to mention that D is the existing elevator into which the pneumatic installation has to discharge its load, G is the receiver, F the filter, C the blower, B the air trap, and A the exit for the spent air; another air trap through which the dust from the filter may be drawn off into sacks. The capacity of the plant is 18 tons of grain per hour, and the driving power consumed is 15 H.P. It has, however, handled up to 22 tons per hour, with an expenditure of 15 H.P. These figures are very satisfactory, principally owing to the lift being only 15 ft.

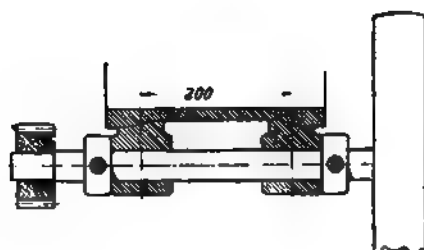
The only details which deserve a fuller description are the air traps B and E, 359 to 362. They consist each of a wheel with six compartments fitting as nearly as possible into a frame, which is cast in one piece with the grain inlet. The same

frame also carries a small countershaft with a pinion which is geared into a large wheel, which in its turn revolves the main portion of the trap slowly. The wheel, with its six compartments, is 16 in. diameter, and 8 in. wide inside.

Another small pneumatic installation is at a mill at Sowerby Bridge, and was erected by Messrs R. Boby, Ltd. The pipe is 4 in. diameter, the total length being 360 ft., and the lift is about 10 ft. The plant had a guaranteed capacity of 10 tons per hour, but it has easily dealt with 14 tons, with a consumption of 35 H.P.

Pneumatic Grain-Handling Plant Mounted on Standard Gauge Railway Rolling Stock.—The requirements of the war made such plant necessary, and the illustration (Fig. 363) shows a photographic view of two trucks comprising such

— 200-200



Figs. 359 to 362. Details of Revolving Air Traps.

a plant. Two of these were supplied for H.M. Office of Works by Messrs Henry Simon, Ltd., of Manchester. Their being mounted on railway trucks permits of their ready removal from one port to another to suit the general requirements.

One of the pair of trucks contains the power plant, comprising the air exhauster and driving mechanism, including the gearing, petrol engine, and accessories. The intake appliances are erected on the second truck, and include the grain receiver, suction dust filter, and two bucket elevators. The machinery is enclosed in a light steel structure built on the wagon and provided with opening windows. Portable quick-coupling suction pipes carried overhead make the connection between the plant and the ship's hold.

The grain, after passing through the plant, is discharged into an outside elevator feeding into weighing machines on a separate truck. The elevator is placed at the side of the truck outside the housing of the remaining machinery, and is arranged so that

it can be brought within the limits of the loading gauge when the plant is required to travel. The capacity of each plant is 30 tons per hour. A similar plant,¹ but on one truck, was built by the East Ferry Road Engineering Works, London, for the Russian Government.

THE PNEUMATIC HANDLING OF ASHES AND COAL

Labour-saving devices for this purpose are one of the latest additions to the ever-increasing number of such appliances. In small boiler plants the ashes are easily handled more or less mechanically by a U-link conveyor, a skip-hoist or a bucket elevator leading to an overhead receptacle to hold the ashes in suspension for loading into trucks or carts by gravity. Such equipments are satisfactory and inexpensive. The upkeep, though proportionately high, is not large in amount. Generally speaking, mechanical conveyors

Fig. 363. Pneumatic Plant Mounted on Two Railway Trucks, as Built by Henry Simon, Ltd., Manchester.

for ashes are unsuitable unless very substantial, as lubrication is difficult or impossible. They are therefore rapidly corroded. Our American friends were the first to apply the Duckham system for handling coal and ashes by pneumatic means. It was introduced by the Darley Engineering Co., of Pittsburg, and installed in many instances by the R. H. Beaumont Co., of Philadelphia. Suction conveyors have no moving parts in contact with the ashes; they are dustless, practically noiseless, and the cost of repairs is only a fraction of that necessary with mechanical conveyors. Fig. 364 shows one of these installations in diagrammatic form. The main ash duct *a* passes close in front of the boilers and beneath the firing floor, but level with the floor are inlets before each boiler, into which the ashes are raked or swept, and which are closed with a lid when not in use. The pipe leads to a large receptacle *b* with cone-shaped top and base, and raised sufficiently high so that the lower end can deliver when opened into a railway truck. The upper cone joins the suction pipe connected to an exhaustor *c*, for small

¹ Described by the Author in *Engineering*, 8th August 1919.

installations, and for large ones to an air-pump. The outlet of this is connected with the chimney whereby the draught is increased. At the top of the ascending pipe, and just before the ashes reach the receptacle *b*, they are subjected to a water spray to avoid dust, and consequently wear on the exhauster. In addition to this the air is withdrawn from the tank through a dust collector.

It is a known fact that in all pneumatic installations for grain, etc., the material travels in the central portion of the pipe, so that no abrasion takes place at the sides of the pipe, except where corners are negotiated, so it was thought necessary to make the bent portions of the pipe not only of a fairly large radius, but also to fit them with renewable cheeks; and as ashes and clinker are of a most cutting nature, the wear on this part is reduced to a minimum by having wearing blocks, *d*, of manganese steel, as shown in Fig. 365.

Fig. 364. Darley Pneumatic Ash-Handling Plant.

The duct *a* is made either of steel or cast iron, and is of a diameter of 6, 8, or 10 in. for capacities of 4, 6, and 10 tons per hour respectively. The tank *b* is made either of steel or concrete. In installations for cold climates the receptacle *b* is fitted with a steam-pipe to prevent the damp ashes from freezing together, which would prevent them leaving the outlet for removal.

An important feature of the suction conveyor is that while removing the ashes, it also removes the hot gases escaping from the ash hoppers, which are a nuisance in the basements of boiler-houses.

With regard to bends, the modern tendency is to use very small radii for these, thus concentrating the wear on a much smaller surface, which can be replaced at far less expense, as with a sharp curve at the bends, the objects merely cannon once or twice and are off again on a straight run. With large curves, however, the material has always a tendency, when travelling through the pipes, to strike the pipe at the bend, rebound

like a billiard ball, and thus strike such a pipe with a large radius again and again until the bend is passed, thus causing scoring all along the whole of the curve, and consequently spreading the wear over a larger surface. The wearing part is always made much thicker at these points to provide for this.

The trend of progress, for which America has set the pace in the direction of employing larger and more numerous boiler units in power installations, must have been the impetus to the introduction of the system in that country.

A typical American plant is that of the Pierce Arrow Motor Car Co., Buffalo, New York, in which both coal and ashes are handled by these means, the coal consumption being about 28,000 tons per annum and the ashes about 10 to 12 per cent. of this amount. The ashes are drawn from the ash pit through 8-in. pipes into a tank which will accommodate 90 tons of ashes, from which they are delivered by gravity into railway trucks. A 3-in. vacuum is kept by the exhaust, and the ashes enter the receptacle at a speed of 5,000 ft. per minute, whilst the air is withdrawn from the tank to the exhauster at a speed of only 700 ft. per minute. This variation in the speed permits of the settling down of the particles floating in the air.

The exponents in this country of the pneumatic coal and ash handling systems are the firms of Messrs Babcock & Wilcox, Ltd., Messrs Ed. Bennis & Co., Ltd., and Messrs H. J. H. King & Co., Ltd., who have installed quite a number of these plants, and in the following we give a concise description of such an installation by Bennis, erected for H.M. Government. The plant is arranged to serve thirty-two

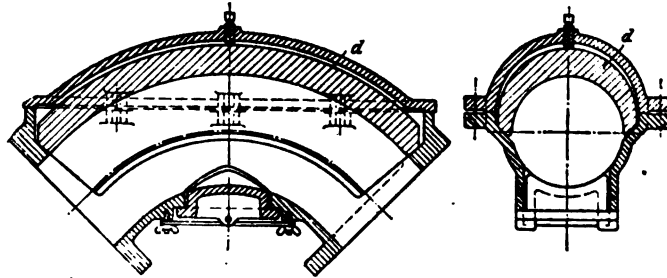


Fig. 365. Details of Bend in Pneumatic Suction Pipe for Ashes and Clinkers.

Lancashire boilers from which it removes the clinker and ash, which it deposits in two steel tanks or receivers. Auxiliary branch lines are provided for cleaning the boiler flues, economisers, chimney bottoms, and so forth. The installation comprises a motor-driven rotary exhauster, foul air cleaner, in addition to the two ash tanks mentioned, as well as the necessary pipe-lines for taking the ash, etc., to the tanks. Openings in the floor plates in front of each boiler flue receive the ashes, each hole being fitted with a dumping hopper, grid, and air cut-off. As the ashes are drawn from the cleaning chamber at the back of the furnace bars of the stokers they are dumped through these openings direct into the ash pipe, and are carried by suction into the ash tanks. The pipes employed for conveying the ashes are of hard cast iron with flanged ends and copper asbestos joints. They are generally carried on brick pillars built into or at the side of the blow-off trench.

The ash tanks, two in number, are cylindrical, with coned top and base, and have a capacity of 20 tons each. They are built of mild steel plates lined with brickwork, angle-iron rings being provided inside the tanks to support the lining. The top of each tank is connected with the ash pipe line, whilst the ashes are freely discharged by gravity at the base.

The tanks are carried on steel structures suitably braced. Platforms, reached by steel ladders, are provided at different stages, for convenience in operating the discharge

valves, water sprays, etc., and a water-sealed pipe is led from the lower portion into a sump to get rid of any excess water and prevent any accumulation.

A larger pipe than that used for the ashes is connected to the upper portion of each tank, and through it the foul air passes to a Bennis patent cleaner or scrubber. This apparatus consists of a water-sealed vessel filled with rows of water-sprayed bafflers which catch any dust or fine particles of ash and prevent them from entering the exhauster. The large water-seal at the bottom of the cleaner acts, incidentally, as a safety valve in case of undue pressure or vacuum in the apparatus.

The method of discharging the ashes from the tank is as follows: A balanced discharge valve is provided at the outlet of each tank, which allows of any required quantity of ashes being withdrawn into railway trucks or other receptacles. The rotation of a hand-wheel first loosens and then releases a catch, allowing the balanced sealing door or valve to drop gently. The rotary cut-off which actually closes the bottom of the ash tank is then opened and as much ash withdrawn into the truck as required, when it is closed again. A touch of the finger brings back the sealing valve into its place, the catch automatically swings back into position, and, reversing the hand-wheel above referred to, tightens the whole mechanism up again, rendering it completely air-tight.

The pipe line for removing the dust from the flues, economisers, and chimneys is entirely separate from the ash pipes, but the two pipe lines are, as a rule, joined together at the foot of the ash pipe leading up to the ash tanks. The flue dust pipes are laid in the cleaning-out pit alongside the economisers, and are fitted with various connections along the length of the main flues and at the entrance to the chimney. The remaining portions of the pipes are generally carried in trenches below the ground level. The flue dust is removed through short, flexible, portable pipes, which can be used for either the flues or the economiser chambers. The suction end of each pipe is provided with a patent nozzle, for which it is claimed that it cannot choke even though it is plunged into a large heap of flue dust. The motor-driven air exhauster is of the rotary blower type. The suction required in this plant is said to be not much more than half that usually employed in grain elevating plants, with a commensurate reduction in the motive power required.

A system based on the fundamental principles of the injector action, but brought more up to date, has been placed on the market by Messrs E. Bennis & Co., under the name of the *Steam Suction System*. The vacuum is produced by a steam jet. This particular type is designed to cope with the needs of smaller boiler-houses, and is primarily for installations where the outlay of capital cost for a pneumatic suction plant is not warranted.

Such plant consists of but few parts, in fact of pipes only, 6 to 8 in. in diameter, the latter being preferable, as they will handle larger lumps of clinker.

An obvious advantage of this type is its applicability to a space too confined for most other types of conveyor.

The action is as follows: After the steam valve has been opened the ashes are raked into the intake of the conveyor and removed, by the suction created by the steam jet, to an overhead hopper, from whence they are removed, as desired, into trucks. The ashes can be carried for a comparatively long distance, say 200 to 300 ft., from the boiler-house and elevated to a sufficient height to be handled by gravity into vehicles, as stated, or the pipe may deliver the ashes on to waste ground without the use of an overhead receptacle.

Quite a number of these pneumatic conveyors are used in the power stations of the

United States Government. Fig. 366 shows the 60-ton tank of the Central Power Plant, Norfolk Navy Yard. Provision is made for weighing the ashes taken from this tank, for the purpose of testing the quality of the coal. The connection with the exhaustor is made through the large diagonal pipe. The 8-in. ash duct is led underground and then rises vertically to the top of the tank. The exhaust pipe is led to the tank *via* a dust collector, which latter is, however, not shown in the illustration.

After many tedious attempts it is now possible to convey small coal from the size of dust to nut coal by pneumatic means. The first successful installation for this purpose

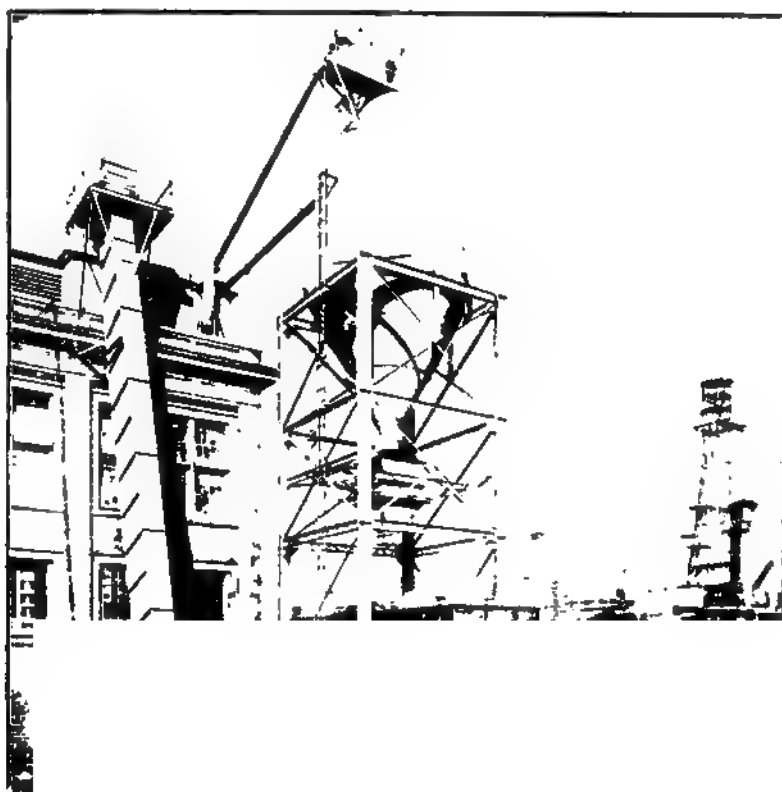


Fig. 366. Pneumatic Ash-Handling Plant at the Norfolk Navy Yard of the United States Government.

has, as far as the writer is aware, been erected in a factory in Austria, where twenty 10-ton truck-loads of coal per twenty-four hours have to be conveyed in order to feed the boilers in the two boiler-houses situated on both sides of the railway line (see Figs. 367 and 368). The continual demand for coal throughout the twenty-four hours cannot be regularly supplied by the railway, so that as a safeguard a stock pile of coal is kept in an open yard about 500 to 600 ft. from the boiler-house.

Before the erection of this pneumatic plant the coal was conveyed in small trucks by hand labour from the wagons or the yard to the boiler-house. From the illustrations it will be seen that the pneumatic installation has been erected just above the railway siding and between the two boiler-houses. It is contained in a tall building, and the

coal is delivered from it by a cross worm conveyor to either or both of the two worms s and s_1 , which distribute it to the coal bunkers. The component parts of this pneumatic plant are not unlike those already described, and consist of the receiver r , two filter chambers f and f_1 , and two air-pumps p , the latter being in the engine-house. Two pipes i and i_1 lead from the top of the receiver r to the lower ends of the filters f and f_1 , and from the lid of these the two pipes k and k_1 lead to the air-pumps p . Below the receiver is the air trap l , and below the two filters are two similar traps l_1 . The former has an outlet for the coal, and the latter for the dust, so that all the coal, large and small, is again reunited in the hopper y . The lower end of the receiver r has three inlets, o , o_1 , and o_2 , with valves for the conveying pipes v , v_1 , and v_2 . The longest pipe v leads to the stock

Figs. 367 and 368. Pneumatic Coal-Handling Plant.

heap in the yard; v_2 is a branch leading to the second stock heap about 130 ft. away, and the pipes v_1 and v_2 lead straight down to the coal trucks on the siding g .

The *modus operandi* is as follows: After two of the valves o are closed so that only one of the pipes v is in communication with the receiver r , a flexible pipe q , with a suction nozzle z , is connected to the pipe, and the nozzle dipped into the coal, as shown in Fig. 369. Air is now sucked out of the filters and through the connecting pipes out of the receiver, when a mixture of air and coal enters the nozzle z , pipes q and v , into the receiver. The air traps are of the revolving type already described, and deliver, as mentioned, into the hopper y . The coal then passes through automatic weighers c and c_1 , and, as already mentioned, into the worms s and s_1 . The dust from the filters is mixed in again in the same proportion as it is received by the nozzle, so that the coal delivered into the worms is exactly of the same quality as received from the stock heap or the railway truck.

The saving of labour effected by the installation was such as to cover its first cost in two years. In addition to the saving of labour there is also the advantage that the coal is emptied more completely out of the trucks, and that there is no loss through the production of dust, which was a great nuisance when hand labour was employed. The installation was built by Seck, of Dresden.

For further installations see "Coal, Coke, and Ash-Handling Plants for Boiler-Houses, Gasworks, etc.," Chapter XLV.

Pneumatic Handling of Coal and Ashes on Board Steamers.—

Pneumatic and hydraulic methods have been satisfactorily in use for the disposal of ashes from steamers for a number of years,¹ but it is a decided innovation to employ one set of apparatus for the dual purpose, for which Letters Patent was granted in Germany during the latter years of the war, to one Conrad Fischer, for a method of conveying the coal by suction from the bunkers and delivering it in the stokehold, which same method and apparatus is likewise used at intervals for dispatching the ashes overboard.

The arrangement of such a scheme is shown diagrammatically in Figs. 370 and 371, the former being a cross section through a steamer so fitted. It must, of course, be understood that the suction chambers may be placed in any convenient position laterally, and would probably not be perpendicularly over the firing room. There are two suction chambers, A and B; the former is essentially for the reception of the ashes, while the latter is for handling the coal. Chamber A is therefore simply connected by pipe K to sea, while chamber B is provided with a wheel trap, which permits the withdrawal of the coal from the receiver. The chamber A is connected by pipe P to the exhaustor. The ashes are raked from the furnaces and sucked by pipe D into chamber A; this pipe is partly flexible, so that it will serve for any

one of the boilers. A larger scale view of chamber A (Fig. 371) shows the essential parts more clearly. From this it will be seen that the suction pipe D enters into the cone-shaped base of the receiver, which latter is divided into two compartments, the lower portion of one being partly filled with water. When the air is exhausted by pipe P the vacuum will suck the ashes up to pipe D, and the heavy substances will settle in the cone, where they escape by pipe E to sea. The dusty air must pass through the water lock in which the series of perforated filtering plates are arranged, so that the air is relieved of most of its dust before passing to the exhaustor. The sediment which accumulates in the water is from time to time allowed to escape by a pipe into the main ash pipe K.

If coal has to be conveyed from the bunkers to the stokehold, the valve H in the suction ash pipe is closed, and a similar valve J is opened in the coal supply pipe L. Since now chambers A and B are connected by pipe M and since valve H is closed, the

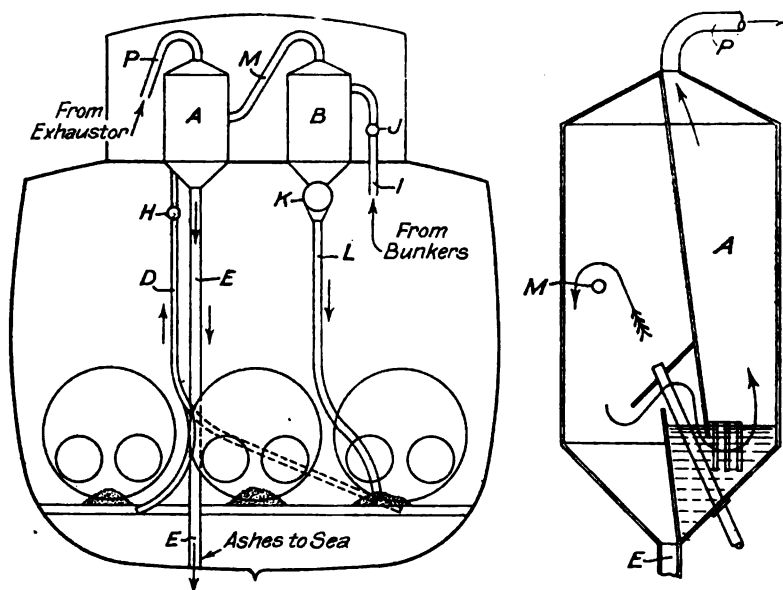
Fig. 369. Suction Nozzle of Pneumatic Coal Conveyor.

¹ See Chapter XXI.

coal is sucked into chamber B, and from this through wheel valve K and pipe L to the floor of the firing room. Pipe L, or rather its lower portion, is likewise flexible, so that the coal can be delivered in front of any boiler where it may be wanted. The same device in vessel A, which purifies the air contaminated by the dust from the ashes, is also used for separating the coal dust, and thus keeping it out of the exhaustor.

With such an installation only one man is required to guide the suction nozzle in the coal bunker, which operation, moreover, will create no dust. When ashes are handled, the suction pipe in the stoking room has similarly to be led into the ash heap. There is no obstruction caused in the stokehold, the only additions to the ordinary equipment being the two pipes for bringing the coal and taking away the ashes, the lower ends of which are flexible.

The above installation is only applicable for small coal, up to the size of nuts.



Figs. 370 and 371. Pneumatic Plant for Conveying Coal and Ashes on Board Steamers.

Pneumatic Plant for Packing Dusty Material into Barrels.—Before concluding this chapter, mention must be made of a device used in the chemical and allied industries for handling a great variety of substances, principally of a powdered or dusty nature. An example of a very simple device for packing such substances into drums or barrels is illustrated diagrammatically in Fig. 372.

A steam jet from injector L sucks air in through pipe G, and the mixture of air and steam passes through a silencer D to the open, or away by pipes. The filling process is as follows: The delivery terminal A is shaped to form a tight-fitting lid. The lower surface fitting against a barrel, is provided with a rubber seating, so that the partial vacuum produced in the barrel will hold the lid A tight. The suction nozzle s is inserted for a few inches into the material to be filled, and is connected by a pipe, part of which is flexible, to the other terminal A. When the steam is admitted into the injector L, a partial vacuum is created in the barrel, so that the outer air rushes into the suction nozzle s, carrying the material with it into the barrel. In this receptacle the air suddenly

expands, so that air and material part company, the former escaping through the injector into the open and the latter accumulating tightly in the barrel. The amount of dust carried away with the air is said to be insignificant.

At the lower end of the adjustable disc r, which is degree of fineness of the reducing the annular space. When the suction nozzle ceases to draw in any material it shows that the barrel is full, as then the disc r is so surrounded with material that it automatically closes the inlet to the barrel. The process is quick: a 40-gallon barrel is filled in 3 to 4 minutes.

Fig. 372. Pneumatic Device for Packing Dusty Material into Barrels or Drums.

This unpleasant and unsanitary work is performed quickly and with a minimum dust production by means of this device, which has, furthermore, the advantage that the barrels and drums are completely filled and tightly packed.

CHAPTER XX

CONVEYING MATERIAL BY HYDRAULIC MEANS

IN the United States experiments have been conducted with satisfactory results, in which small coal was mixed with and conveyed in a stream of water through pipes, and at the destination the coal was allowed to settle whilst the water was led away. What has been said in connection with pneumatic conveyors applies also to this system, viz., the material to be conveyed should not have a specific gravity much greater than the medium in which it travels, otherwise the speed of the mixture in the pipes must be greater, and therefore the expenditure of driving power higher. This rule applies to the conveyance of coal by means of currents of water. The flow must be swift enough to prevent the coal from separating and depositing, thereby blocking up the pipes, particularly where these are laid horizontally. It may be of interest to see what else has been conveyed by these hydraulic methods. Ice has been similarly handled for many years in America, and sugar beet is pumped in continental sugar factories; but then ice is lighter than water, and beetroot, at any rate, not much heavier.

Material from dredgers, such as sand and mud, is frequently conveyed by such means, water being mixed freely with the material, which is thus conveyed on to waste land. This fact can only be briefly mentioned without going into details, as it would be beyond the scope of this work, in which also dredgers and power shovels have been omitted, as digging and excavating, and not conveying, are the primary and more important objects of these appliances.

Hydraulic Coal Conveying at the Hammersmith Borough Council's Electric Power Station.—The problem with which Mr G. G. Bell (engineer and designer of the plant) had to deal, was the difficulty in getting his coal (about 100 tons per day) into the works. It was impossible to get a siding from Hammersmith Station, and the wharf where most of the coal is landed, though only about a third of a mile from the power station, is not easily reached by vehicular methods, as the heavy traffic in Fulham Palace Road has to be crossed. In consequence, the cost of getting the coal from the wharf to the power station amounted to about 7d. per ton, which was considered very heavy under pre-war conditions then obtaining. Wayleave for an overhead conveyor scheme was also out of the question in that thickly populated neighbourhood. For pneumatic handling the distance was too great and the power consumption would therefore have been too high, so Mr Bell conceived the idea of pumping his coal (being unaware that an installation on these lines was erected some years previously, in America, for the National Zinc Co., details of which have not, so far as the writer is aware, been published), and thus succeeded in conveying the coal at the low figure of 3d. per ton, including driving power and manual attendance but minus the interest on capital expenditure, which is very small per ton if the installation is in full work.

The coal arrives at the wharf in river barges holding from 50 to 150 tons. These are unloaded by crane and grab in the usual way, and successive grab loads are discharged into a large overhead steel receiving hopper on the quay (see diagram, Fig. 373). This hopper is covered with a grating with a 5-in. mesh, so that all coal which passes this

mesh will pass through the plant. Beneath this hopper is an Avery automatic weighing machine with a totaliser, which keeps a record of the coal so received. (At the date of the writer's visit, 9th February 1920, the index showed that 43,460 tons had passed this machine and been pumped to the station since 1915.) After the weight of the coal has thus been recorded it is dropped into a smaller hopper with a cone-shaped outlet, which delivers in turn upon the revolving disc of a Mitchell patent feeding device, thus converting the intermittent coal supply from the grab and weighing machine into a continuous one.

A rectangular steel tank about half filled with water is the next recipient of the now continuous stream of coal. This tank may be considered the receiving terminal of the pumping plant in which the water and coal are automatically mixed and sucked into the inlet of a 7-in. Gwynne's centrifugal sludge pump driven by an electro-motor, the delivery pipe of which is connected with the 8-in. main pipe-line which leads to and delivers into one of a series of receiving tanks at the power station, each 50 ft. in diameter and 30 ft. deep. The pipe-line has branches, and by ordinary sluice valves the stream of coal and water can be directed into any one of the delivery tanks.

There is a difference in level of 6·9 in. between the receiving and the delivery tanks, so that the coal travels on a rising gradient. The mixture of water and coal travels at the rate of 4 ft. per second.

The proportion of coal to water is about half and half, when small coal or slack of the ordinary kind for feeding automatic stokers is handled; for larger coal the proportion of water is greater. The delivery pipe terminates several feet above the delivery tank, and the jet, which is of a dull black colour, seems to have lost nothing of the liquidity of ordinary water. The pipe-line, which is fitted with a swivel joint, is generally directed into the centre of the delivery tank, from which a locomotive crane and Priestman grab reclaim the coal, which is either allowed to drain in one of the five tanks or is delivered direct on to the band conveyor which feeds the boilers.

The water circulates so slowly through these large tanks that practically every particle of coal can settle before the water is drawn off through perforated plates and led back through a return main pipe of the same nature to the receiving tank. A small

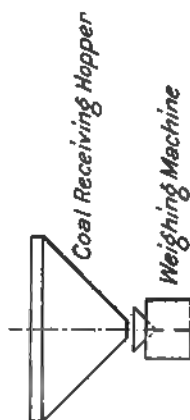


Fig. 373. Diagram showing Principle of Hydraulic Coal-Pumping Installation at Hammermill.

electrically driven centrifugal pump is built into this return main at the power house end. This has been found necessary in spite of the gradient in favour of gravity. As the proportion of coal and water in the mixture changes with the size of the coal to be handled, it becomes necessary to admit additional water into the circuit when larger coal is being handled. This is allowed to enter into the receiving tank from the return main through a valve controlled by a float. If additional water is necessary, or if by some mischance the return water supply should fail, Mr Bell has arranged for a branch pipe from his condenser main—which is opened automatically—if the water level in the receiving tank sinks below a certain level. This is a wise and necessary precaution, because a shortage of water in the conveying main would cause the coal to settle in the pipe with the consequent stoppage of the system.

When a barge has been emptied, the water is permitted to circulate for ten minutes after the coal supply has ceased, in order to be sure that all the coal has been cleared out of the pipe.

Another safety precaution is the provision of a storage dump upon which the crane and grab at the quay can discharge. This same expedient is, however, provided in the first instance to meet the case when the five coal storage tanks are full. The storage tanks hold 1,750 tons of coal each, stored under water, and thus immune from the inherent trouble to which ordinary coal stores, particularly those for fine coal, are subject, on account of spontaneous ignition. An extraordinary fact is that these tanks were intended for a capacity of 1,500 tons, estimated on a basis of 40 cubic ft. per ton; but the coal lies so close together in this case, being practically without any interstices, that each tank will hold 250 tons more. This was found out owing to the fact that 1,000 tons of coal, which should have been in the store, could not be accounted for until the matter was investigated.

The structural terminal receiving tower was supplied by Messrs Fraser & Chalmers. The mains are laid in the streets in the form of a large S-bend, and consist of Mannesmann tubes with an internal diameter of 8 in. and in 30-ft. lengths. They are of the socket and spigot type, the joints being made of lead wool and tested to 300 lb. per square inch.

The total length of the plant is 1,760 ft.; the power consumption is 50 H.P.; while the capacity is 50 tons per hour of coal. It might be mentioned that there is no perceptible difference in power consumption, whether the plant is running idle or conveying coal.

The consumption of electrical energy varies, and if coal in the barges has to be trimmed, the power consumption goes on and the expenditure per ton is therefore higher. The highest record is 6 to 7 units, but when regularly at work the expenditure is only 3 units per ton of coal.

There are several bends in the pipes, the largest being of a radius of 53 ft.; there are several of 3-ft. radius, and one which has a radius of only 1 ft. It can therefore be seen that the coal and water mixture negotiates almost any bend which can be negotiated by plain water in pipes.

The whole scheme is so extremely simple that one can only wonder that something similar was not done long ago. A little tuning up has been necessary in order to simplify the plant since first it was erected in 1914. There is, however, only one point in which further improvement appears possible, and that is in the feeding of the coal to the main pipe. It might be better to feed the coal into the pipe at a spot beyond the pump instead of before it, so that the coal need not pass through the pump. This construction is customary in the pneumatic system when working with pressure, and there is no apparent reason why it should not be applied to the hydraulic system.

The cost of the installation was estimated to be £15,600, and by its use an annual saving of £1,577 may be effected.

CHAPTER XXI

THE MECHANICAL DISPOSAL OF ASHES FROM STEAMERS

THE tendency to utilise mechanical means for handling material has become more and more general, and important new fields for their operation have, within recent years, been opened up in the mechanical disposal of ashes and clinkers from the stokeholds of steamers.

Development of Ash Ejection.—In the days of marine engines of small horse power, and consequent small coal consumption, the refuse of the stokehold was easily dealt with by hand labour, being brought up in buckets and emptied over the side. When the coal consumption had sufficiently advanced to warrant their adoption, simple ash hoists were introduced, still utilising the bucket or skip, the general procedure remaining much the same, except that mechanical means were employed to raise the buckets to the deck level, or a yard or two above it.

The ashes or clinkers from the boilers of large modern steamers accumulate so fast that they have to be removed about every four hours from the furnace. After being cooled with water, they are generally filled into large iron tubs on wheels, which sometimes run on rails to a suitable position, whence they can be raised to the deck, and the ashes tipped overboard at intervals.

The older methods employed ordinary hoists, by means of which the tubs were either raised through a special duct or shaft, or more often one of the ventilating shafts was used for their passage. On deck corresponding rails were provided, on to which the tubs were lowered and pushed to the ship's side, and emptied into hopper shoots leading overboard.

The Ash Hoist.¹—All ash hoists have certain limitations; they cause the intolerable nuisance of ashes being blown all over the deck of the vessel, to the annoyance and discomfort of passengers and crew. This is especially the case with passenger vessels in hot climates, owing to the ashes being blown into the cabins through the open portholes. If the operation of the hoists is restricted to night time, the noise produced by them is also objectionable. Ash hoists are, moreover, restricted to steamers working without forced draught, on account of the communication which the duct affords between the stokehold and the open. Worst of all, they are too slow and altogether inadequate for large steamers. With modern equipments of more powerful engines, and, consequently, much larger coal consumption, the disposal of ashes called for a more efficient method. This led to the introduction of the hydro-ejector, which, as the name implies, ejects the ashes by hydraulic force, or, rather, by jets of water under pressure. This system answers very well, and is largely used in merchant steamers, notwithstanding sundry drawbacks. In the case of battleships it was soon decided that the piercing of the armour to provide outlets above the water line for the ashes was undesirable on account of weakening the armour.

Hydro-Ejectors.—Hydro-ejectors were first introduced by Horace See, of New

¹ Ash hoists are fully described in an article by the Author in *Cassier's Magazine* of August 1912.

York, and his system is shown by Fig. 374. On the stokehold floor is fixed a hopper *A*, fitted with a water-tight lid *B*, and fastenings *g h*. The hopper *A* communicates with the ejector pipe *C*, at the base of which is a hydraulic nozzle *F*, regulated by cock *E*, and fed from the pressure main *D*. Pipe *C* is bent at its upper end and delivers the ashes overboard above the water line. Air may be admitted through an air valve *I*, during the conveying action, and a cock *c* is provided for emptying the water out of the apparatus after use.

The ejector works as follows: After the cocks and valves *c*, *E*, and *I* have been closed, the lid *B* is opened and the ashes filled into hopper *A*; the pressure pump is now started. As soon as the gauge indicates the required pressure, the cock *E* is opened quickly and the water under pressure enters through jet *F* at a high speed and forces the ashes through pipe *C* overboard. At the same time, tap *I* is opened to admit air, which acts like an injector in dispersing the ashes.

Fig. 374. Arrangement of See's Hydraulic Ash Ejector.

If the ashes contain large pieces of clinker, a grating is placed on top of the hopper *A*, and the pieces which are too large to pass, broken with a hammer, to prevent the choking of the pipe *C*. This system has the drawback that, unless the pressure gauge is carefully watched and the cock opened at the exact moment, the pipe *D* or the pump might be injured. The inventor has therefore added an automatic device to prevent this. In this modified scheme the jet nozzle is closed by a rod which carries two pistons of different diameters, while a spring also holds this rod in position. The whole of this is enclosed in an iron cylinder which communicates by a branch pipe with the hydraulic main. As soon as the right pressure in the main is reached, the valve opens automatically and the ashes are ejected. When the ashes have been disposed of, a three-way valve is set to permit the water to escape in front of the piston, when the nozzle will automatically close.

Generally, one of these ejectors is used in connection with each stokehold; but the inlet can also be duplicated to serve two stokeholds, as shown in Fig. 375: *ff* are the two lids of the hoppers *A A*; they are so connected by chain *h* that only one can be opened at a time. This construction has several disadvantages.

Fig. 375. Arrangement of See's Ash Ejector to serve two Stokeholds.

As there is always a tendency for the finer ashes to accumulate in the base of the hopper, where they are out of reach of the water jet, Thorne has constructed a hopper as shown in Fig. 376. This permits a portion of the water from the hydraulic main *A* to pass through a narrow channel *g* into the hopper, and thus keeps it clean. The amount of water so used can be adjusted by the valve *f*.

Another method is that of Hochstein, shown in Figs. 377 and 378. It is for a

similar purpose to See's attachment. Both have the object of preventing shocks in the hydraulic mains at the setting to work of the apparatus, and preventing unsatisfactory starting owing to insufficient initial pressure. This is achieved by Hochstein, who allows a circulating pump to be always at work, and his apparatus permits, by the movement of a lever, of utilising

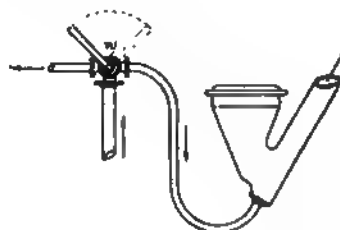


Fig. 377. The Hochstein Three-way Valve.

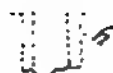


Fig. 376. Outline of the Thorne Hopper.

the water either for the ejector or for returning it to sea. The simplest application of a three-way valve *w*, shown in Fig. 377, explains itself. It shows the hydraulic main leading to the valve *w*, which conducts the water either into the ejector or to sea. The shock preventer is illustrated in Fig. 378. The hydraulic main enters at *e*, and the water can enter either through jet *b* to the ejector or through jet *c* to some other exit; the jets *b* and *c* are respectively opened or closed by the valves *k* and *i*, which latter form part of a hollow spindle with the openings or ports *d*, *f*, and *g*. Attached to this spindle are the pistons *r* and *s*, of different diameters. When the three-way valve *a* is opened, as shown in the drawing, the pipe *p* forms a communication between the hydraulic supply and the larger of the two pistons, and thereby opens jet *b* and starts the ejector with full pressure. When valve *a* is closed, the water enters the ports *d*, in the hollow spindle, and passes through ports *g*, below the smaller piston, and forces the valves into the position shown—that is, the ejector valve *b* is closed and the water escapes through the ports *f* and exit *c*. It will thus be seen that by opening or closing valve *a* the ejector is started or stopped immediately.

As it is most essential, for obvious reasons, that the discharge of the ashes should take place at will, either at the port or starboard side of the steamer, ejector installations have either to be provided in duplicate, with the exit on different sides, or if one installation only is to be used, it must be provided with alternate exits, one to port and one to starboard. A scheme providing for this, also the invention of Hochstein, is shown in Fig. 379, where *a* represents the ash hopper, *b* the ejector pipe, and *c* the two outlets. By the movement of a lever the valve attachment *c'* conducts the ashes to either one side or the other. The two smaller

Fig. 378. Hochstein's Method of Preventing Shocks in the Hydraulic Mains.

illustrations, Fig. 380, show two sections through the principal parts with the movable distributor *d* and the bend *b*¹ of the ejector pipe.

The hydraulic ejector by Korting, of injector fame, is represented in Fig. 381, and shows development in the right direction. The ejector pipe *b* leads by a bend into the larger pipe *c*, which terminates at the ship's bottom, or an alternative outlet under water at the side, as shown in dotted lines; *d* is a perforated plate to prevent dust, while *e* is an air inlet, which ensures that the water level is the same in the pipe *c* as outside. The following data are available in connection with this ejector: Water at a pressure of 180 lb. per square inch was used, and passed to the ejector through a 2½-in. pipe. With this apparatus it took 3,300 gals. of water to eject 7 to 8 tons of ashes to a height of 13 to 14 ft. through a 4-in. pipe.

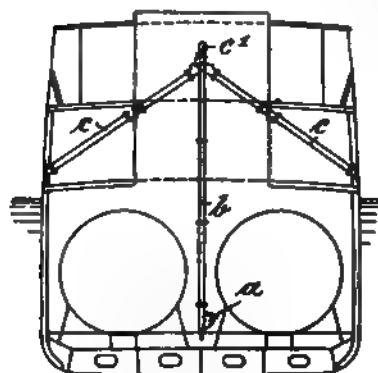


Fig. 379. Hochstein's Method for Discharging Ashes to Port or Starboard of a Vessel.

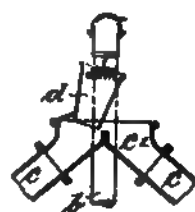


Fig. 380. Details of the Principal Parts of Fig. 379, in Front and Side Views.

Ejector Pipes.—Bends in ejector pipes are subject to enormous wear and tear by the clinkers, and owing to the centrifugal force when negotiating bends all the abrasion takes place on the one side and under the most adverse circumstances. The pipes have therefore to be of thicker metal on the side most affected, or with renewable liners. Such liners have been made of glass, which is harder than ashes, which is said to reduce the cost of renewals.

There can be no doubt that, where possible, the ideal exit for the discharge of ashes is vertically down through the ship's bottom, as this method has the following distinct advantages: The discharge pipe is short and straight (without bends); it makes the

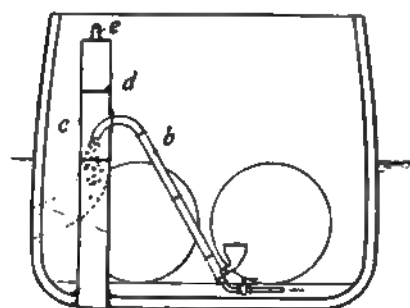
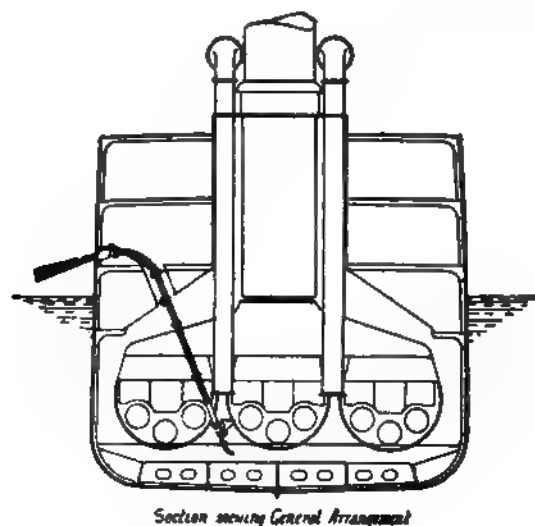


Fig. 381. Arrangement of Korting's Hydraulic Ash Ejector.

passage of pipes through the bunkers and decks unnecessary; the condition of the weather is immaterial to the successful expulsion of the ashes, contrary to side delivery above the water line, as such installations have frequently to be fitted in duplicate, as already mentioned, to enable the discharge of ashes to leeward in all weathers, and even then a head or following wind will cause the seas to carry the ashes back on to the deck, as well as into the stern tubes and sea suctions, and the ashes will cause scoring of the skin plating at and below the water line.

The system introduced by Horace See, though exceedingly simple, requires very careful attention to all its details, and although an ejector of imperfect design may handle the ashes very well, the cost of renewals and repairs, and, shall we say, the life of the machine, depend upon the excellence of construction of the vital parts.

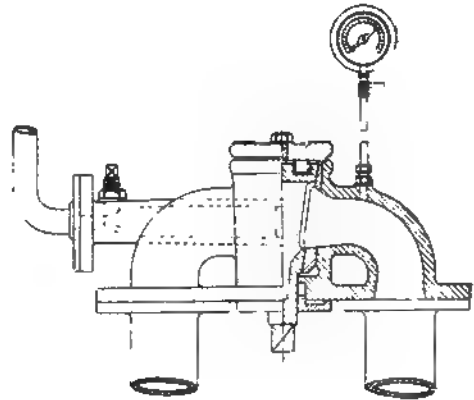


SHIPS SIDE

Figs. 382 to 386. General Arrangement and Details of Trewent & Proctor's Ash Ejector.

One of the ejectors as now built by Trewent & Proctor Ltd., and installed in steamers, is represented in Figs. 382 to 386, with the details to a larger scale. The system has already been described in general outline, and is so simple that it requires very little further comment.

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Figs. 387 and 388. Two Types of Trewent & Proctor's Control Cock.

The receiving hopper *w* for the ashes is fitted with a grating to prevent large objects from falling in; it is also provided with a water-tight lid. The knee piece *τ*, which supports the lower terminal of the apparatus, also bears the nozzle for the jet, an inspection hole *s*, and an air inlet. The cock *p* controls the ejector jet from the hydraulic main. The other letters on the illustrations represent respectively: *m* the pressure gauge, *D* the hydraulic main, *v* the discharge pipe, *v* the bent portion of the delivery pipe, *x* removable segments of the same pipe, and *z* the ship's side valve.

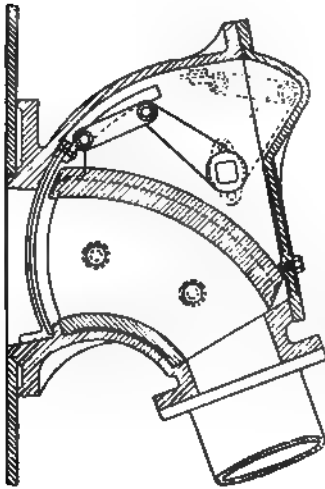
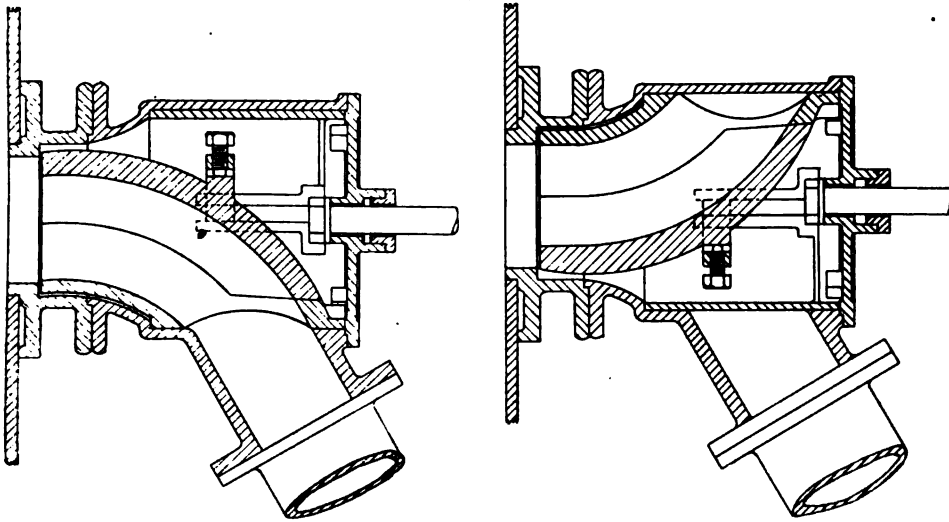


Fig. 389. Ship's Side Valve of Ash Ejector.

The operation is as follows: As soon as the pressure in the main from the pump has reached 190 to 200 lb. per square inch by the gauge *m*, the control cock *p* is opened quickly, when the pressure will fall to 150 lb., and must be maintained at that. The jet so admitted into the discharge pipe will eject any ashes or clinkers filled into the hopper *w* at great speed through the ship's side valve *z*, which, of course, has been opened previously. The control cock *p* is a very important part of the system, and a separate illustration of this detail is therefore given in Fig. 387. The bore of the cock gently tapers from the supply pipe to the nozzle, and the interior of the movable part is fitted with an escape valve which opens at a pressure of 200 lb., allowing the water to the bilges. The nozzle is separate so that different sizes can be fitted to suit different heights of lifts for the ashes. Sometimes a by-pass branch is fitted to the cock for use when the ejector is shut off. A modified form of control cock is shown in Fig. 388. This type is fitted on the bulkhead and connected by a separate pipe to the

ejector piece *r*. The nozzle in this case is fitted to this latter part. As the illustration shows, there is also a by-pass branch and a pressure gauge. The whole apparatus



Figs. 390 and 391. Revolving Cock Outlet in the Open and Closed Positions.

connecting the pump to the nozzle must stand a pressure of 200 lb., and the hydraulic mains must have as few bends as possible.

Having now dealt with two of the principal forms of receiving terminals, we will pass to the equally important delivery terminals. Fig. 389 represents the construction of

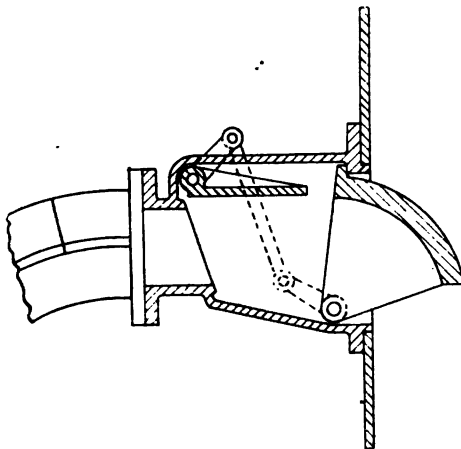


Fig. 392. Valve Outlet with Deflector.

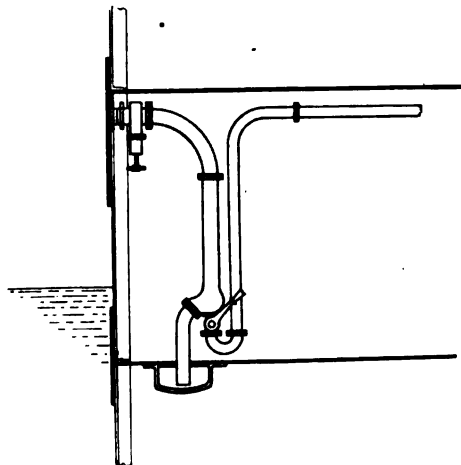


Fig. 393. Ejector for Dung.

a ship's side valve, which dispenses with the usual bend (shown in Fig. 383) at the top of the ejector pipe, as the ashes are deflected in the desired direction by a plate inside the valve. Renewable side and bottom plates are also provided. The principal feature of the valve is the curved sliding shutter, which closes the discharge opening between the

deflecting plate and the ship's side. A hydraulic cylinder is sometimes used to open the shutter automatically when the ejector is working, and which closes by a weight as soon as the apparatus becomes idle.

A patent revolving cock outlet, fitted with a deflecting plate, is shown in Figs. 390 and 391, which answers the same purpose as that in Fig. 389. This type is used for destroyers where lightness is a consideration, and for small steamers. The two illustrations show the cock open and closed.

Yet another type of outlet with deflectors to discharge the ashes close to the sides of the vessel is shown in Fig. 392, which explains itself. The apparatus is quite housed within the ship when out of use and closed.

The same ejector, with slight modifications, is used on steamers carrying horses to discharge the dung from the lower deck. Fig. 393 shows this application of the ejector. The refuse is swept or swilled to the ejector, where it is sucked up and expelled overboard.

Latest Developments.—With the advent of the recent types of battleships and cruisers with their powerful turbine engines, the question of the mechanical disposal of the now enormous quantities of ashes has become a most important one. The non-interference with the existing structural arrangements was a *sine qua non*. The Admiralty, while seeking a solution of the difficulty, experimented with an ejector used in the French Navy, with a discharge through the ship's bottom, but it did not answer the requirements of the British Navy; and after further investigation and experiment, produced a system by which the clinkers, ashes, and other refuse were first crushed and then expelled by pneumatic pressure through an opening in the ship's bottom.

Before describing the system adopted by the British Navy, a brief description of the device used by the French Navy may not be out of place.

Fig. 394. Compressed Air Ash Ejector of Brouquière & Baze.

The compressed air ash ejector of Brouquière & Baze is shown in Fig. 394. The ashes are deposited through the opening *c*, which closes water-tight; the door of the opening *c* is manipulated by the piston and rod of the pneumatic cylinder *a*; the pipes *m* and *i* supply the air from the main. The ashes in the hopper *A* are mixed with water, and are agitated by a stirring device (not shown) manipulated by spindle *b*. The exit of the hopper *A* is closed by a floating valve *e*, which may be opened by the rope *d* connected to a piston in the pneumatic cylinder *e*. Water can be admitted into the hopper *A* from *o*, which is normally full of sea water, through the tap *g*, whilst the compressed air is admitted by cock *h*. The delivery pipe *n* for the ashes may be closed by gate valve *k*.

The apparatus acts as follows: Compressed air is admitted below the piston in cylinder *a*, whereby the door *c* is opened. After the filling of the hopper, door *c* is again closed by admitting air above the piston of cylinder *a*. The gate valve *k* is now opened

to admit sea water, whereby valve *c* is automatically closed and tap *g* is opened to let water in by pipe *f*, so that the hopper is filled, when the stirrer is set to work. Compressed air is now admitted beneath the piston of cylinder *e*, which, by means of the rope, opens the floating valve *c* into the position shown dotted, thus giving a free exit to the mixture of ashes and water. Compressed air is at the same time admitted by cock *h*, which forces the ashes out.

The System on which the ashes are disposed of in the **British Navy** consists of two types, both of which are built by J. Stone & Co. Ltd., of Deptford, namely, the pneumatic under-line ash and clinker expeller, used largely in His Majesty's Navy, and the hydro-pneumatic under-line ash expeller specially designed for first-class turbine battleships and cruisers. The former type discharges vertically downwards, while the second discharges generally through the side of the vessel beneath the water line, as shown in Fig. 395. It was necessary to have a side discharge, owing to the fact that the main condenser suction in the latest turbine battleships are situated in the bottom of the ships, so that an ash discharge vertically downwards would make it possible for some of the ashes to be taken into the suction, with disastrous results.

Fig. 395. Diagram of Stone's Patent Hydro-Pneumatic Under-line Ash Expeller used for Naval Purposes.

Figs. 396 and 397. Arrangement of Crusher for Breaking Clinker for Discharge through Stone's Expeller.

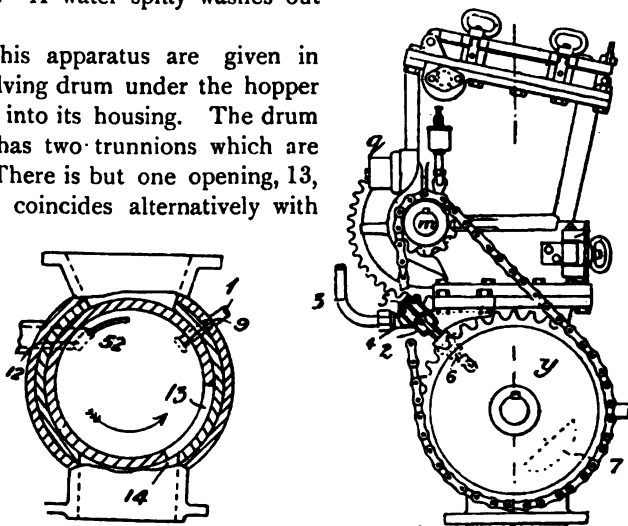
Stone's under-line pneumatic ash and clinker expeller consists of a hopper into which the ashes, etc., are shovelled as they come from the furnace. From the hopper the material falls into a pair of crushing jaws, which reduce it to a convenient size for effectual discharge. The ashes so reduced are now received intermittently into a revolving drum,

which at one period of its revolution receives a charge, whilst at another it allows this charge to escape to sea. It thus at no time allows a communication between the sea and the ship's compartment. Finally, a gate valve is introduced between the exit and the working part of the apparatus, only to be closed to keep the sea out if repair should be necessary. An engine combined with an air compressor furnishes the driving power for the crusher and drum, and also the pneumatic supply for the same. In Figs. 396 and 397 the crushing jaws *i* and *h* are shown; the latter is fixed, whilst the former is pivoted at the top, and made to reciprocate at its lower end by a revolving three-lobed cam, which is keyed to the spindle *m*. A draw-back rod, actuated by a volute spring *p*, in case *q*, keeps the face of the jaws always in contact with the cam face *r*. The shaft is driven by roller chain and chain wheels at a speed of 60 revs. per minute, giving the hinged jaw about 180 double strokes per minute. There is an inspection door to give access to the lower part of the hopper, and the whole apparatus can be closed by a water-tight cover. A water spray washes out and keeps the hopper clean.

Two further views of this apparatus are given in Figs. 398 and 399. The revolving drum under the hopper is conical, and fits like a cock into its housing. The drum consists of one casting, and has two trunnions which are supported by two bearings. There is but one opening, 13, in the revolving cone which coincides alternatively with the inlet and outlet of its casing. The chain-wheel *y* receives power from the crusher spindle. In order to assist and expedite the expulsion of the ashes, compressed air is admitted into the drum by air-pipe 3 and valve 2. This valve is opened automatically as soon as the drum has attained the position at which the air cannot escape out of the hopper. There is a tripper, 7, on the chain-wheel *y*, which opens the valve 2 just at the right moment once in every revolution. The air is then admitted by pipe 1 and the opening 10. When the drum is in position, shown in Fig. 396, water is also admitted by pipe 16 and the spreaders 17 and 18, which cause a spray and prevent the creation of dust. Fig. 399 shows an outside view, from which the tripper 7 and the air valve can be better seen. In the sectional view, Fig. 398, the drum is shown in the position in which opening 13 is just closing after discharge into exit 14. The compressed air prevents the sea from entering whilst the ashes escape. Just before opening 14 is closed again by the revolving drum, a communication with the atmosphere is established by opening 12 and pipe 12.

The *hydro-pneumatic under-line ash expeller* is similar to the last, and a general disposition is shown in Fig. 395. In this arrangement a stream of water, which is drawn from the sea by a centrifugal pump, is continually moving through a discharge pipe which passes beneath the expeller.

The ashes and other refuse are shovelled into a crushing hopper, whence they pass



Figs. 398 and 399. Details of Crusher and Drum of Stone's Ash Expeller.

The ashes and other refuse are shovelled into a crushing hopper, whence they pass

into a double-ported revolving drum, similar to that above described, which alternately presents its openings to the hopper and to the moving stream of water beneath, so that the ashes are caught by the stream and carried several feet clear of the ship's side, or bottom, according to the place from which they are discharged.

Both the air compressor and the centrifugal pump are coupled to a two-crank, single-cylinder steam engine, which is also used for driving the crusher and the revolving drum.

The ash discharge pipe may be either vertically downwards through the ship's bottom, horizontally through the side, or inclined at an angle, as shown in Fig. 395.

Both types of under-line ash expellers are fitted with knife blades at the drum and its casing, to shear off any material which might find its way between the revolving surfaces. There is, in addition, a safety device, which on entry of extra hard material causes the breakage of a small safety pin and stops the machine. Upon the shearing of this pin the steam-driven compressor is immediately stopped by an automatic arrangement, which makes a steam governor unnecessary. These pins are easily replaceable, and a number are carried as spare parts.

All the later vessels of the British Navy are now fitted with these ash expellers, as well as the most important of the liners, including those of the Cunard, White Star, P. & O., etc.

Stone's Ash Expeller.—The latest type of Stone's ash expeller is exclusively worked by hydraulic means, the apparatus being known as Stone's Patent Hydraulic Ash Expeller. Figs. 400 and 401 show the construction, whilst Fig. 402 shows the expeller as installed on board. The first illustration represents the expeller when shut off, and the second when in use. The working part of the machine is entirely below the stokehold floor, the receiving hopper being on a level with the floor, so that the ashes and clinkers are merely swept into it.

The expeller consists of the receiving hopper already mentioned, and this is fitted with a grating, the wide bars of which reach into the hopper to within a few inches of its sloping base, thus preventing larger pieces entering the apparatus than can be conveniently and safely expelled.

A number of auxiliary water jets play upon the ashes, swilling them down the gentle slope of the hopper, and bringing them to the point where they come within the reach of the induced current.

A copious water supply at a pressure of from 15 to 20 lb. per square inch from a centrifugal pump is used and is sufficient to eject the ashes, etc., at a velocity of 20 ft. per second from the ship's side. It is of importance that this speed should be maintained, and it is one of the functions of the apparatus to do this automatically.

The *modus operandi* is as follows: The ashes are swept to fall through the grating A into the hopper B, and proceed from this, as already mentioned, by the aid of auxiliary water jets into the small hopper or chamber C, the passage between B and C being interceptible by an automatic hydraulic ram D. This is normally open when the ejector is at work, but throttles the communication automatically immediately any overfeeding should retard the velocity of ejection, and thereby temporarily checking the admission of ashes. As soon as normal conditions are re-established, the ram withdraws automatically and so makes the full opening again available. The ram in its movement does not only control, as we have seen, the communication between B and C, but it also controls the starting and stopping of the flushing jets in the hopper B, and thereby retards or accelerates the movement of the ashes.

The hydraulic ram D is a differential one; it fits into the cylinder E in such a way that it offers surfaces of different areas to the water pressure at both sides. The smaller

area of the ram is exposed to the sea water pressure (due to the immersion of the ship), and the larger area to the secondary cone flow between G and H.

As soon as the flow of the ejector water from the jets F, G, and H is sufficiently powerful to create suction, and thereby reduce the pressure at the secondary cone

Fig. 400. Stone's Hydraulic Ash Expeller Shut Off.

opening, which is in communication with the larger area of the ram, the sea water pressure on the smaller area of the ram becomes sufficiently powerful to move the ram and open the way for the ashes. These remain stationary in the hopper until the small auxiliary jets of swilling water are started, which happens as soon as the ram has completed its full stroke and has reached the extreme backward position. In this position the large end of the ram exposes a port to the water on the small area, which opens a valve by a piston to which the large ram acts as a valve, and then passes on and flushes the hopper, releasing the ashes.



Fig. 401. Stone's Hydraulic Ash Expeller when Working.

Should the quantity of ashes with the incoming flush from the hopper be too great, and therefore reduce the speed of the ejector flow and simultaneously allow pressure to form on the larger area of the ram, and so overcome again the sea pressure at the smaller area, the ram moves forward again sufficiently to cut off the flushing water, and reopens immediately the correct speed is re-established.

If the water jet of the expeller should be stopped purposely or accidentally whilst the ship's side valve is still open, the seas entering the discharge pipe would enter also the cone opening G H, and act upon the larger area of the ram and so immediately close any communication between the sea and the stokehold.

The ashes which have been admitted into the chamber c are expelled immediately by the jet from nozzle F into the sea. Cone opening g, being the only part exposed to more than ordinary wear and tear, is interchangeable. At the end of the ram a valve is formed for closing the exit from the base of the hopper b. There is also a scraper provided for the purpose of cleaning the seat of the valve, preparatory to its finally

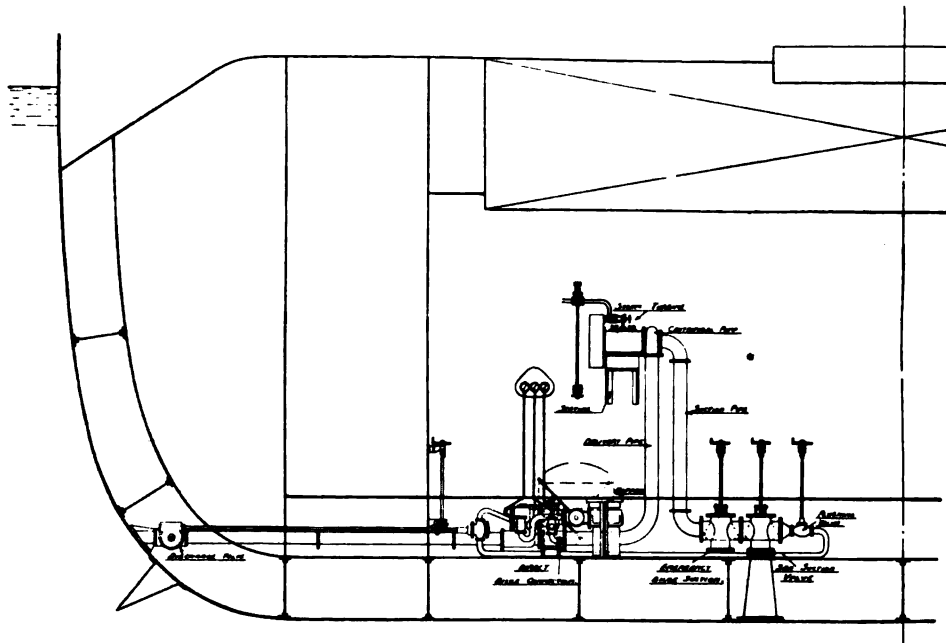


Fig. 402. Section of Ship showing General Arrangement of Stone's Ash Expeller.

closing, and a stream of water, issuing from a point immediately above the valves, swills away any ashes which may adhere to the valve or its seat.

The working of the expeller is noiseless, continuous, and automatic. The horse power expended in working one of these is 30 brake H.P., when expelling ashes at the rate of 10 tons per hour.

The "Mauretania" was the first vessel fitted with such an installation, and at the trial as many as four barrows of ashes were expelled in one minute. The "Aquitania," "Mauretania," and "Lusitania" are fitted with these expellers, and twelve of the new Iron Duke class of battleships are fitted with three each, also three of the battleships of the Spanish Navy and four of the Japanese Navy. Numerous other vessels are fitted with these expellers, including eleven of the White Star Line; and some thirty others of various steamship companies. This expeller is the outcome of many experiments which have been conducted by Messrs Stone during the last seven years.

INTERMITTENT HANDLING OF MATERIAL

CHAPTER XXII

INTRODUCTORY

UNDER this heading are included mechanical appliances by which material is handled intermittently and in suitable receptacles, and not in bulk in a continuous stream.

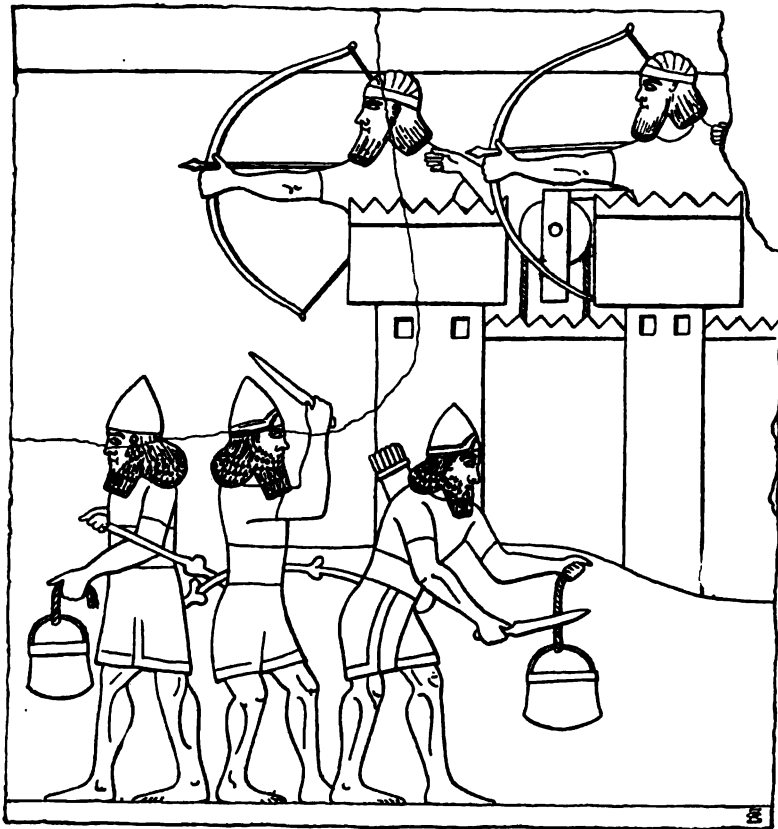


Fig. 403. Assyrian Bas-Relief showing Use of Rope and Block, from the Original in the British Museum, with the Upper Left-Hand Corner Restored.

While in continuous handling plants the material is transported in an unbroken stream, or practically so, in intermittent handling the material is filled into and carried by receptacles; or where the individual objects to be conveyed are too large to be taken

into such receptacles, they are handled individually by suitable supports in a succession of single loads. The form of the receptacles, when such are in use, varies according to the method adopted, and to the nature of the material being dealt with.

The methods of intermittent handling described in the following pages are classified under the following heads:—

(a) **Endless Rope and Chain Haulage**, in which the load is contained in narrow gauge trucks running on ordinary rails, and propelled by a continuous hauling rope between the receiving and delivery terminals.

(b) **Ropeways, Aerial Cableways, and Appliances for Coaling at Sea**, where a similar process to the preceding one is employed, with the exception that instead of the receptacles running on rails on the ground, they are suspended from a rope above the ground.

(c) **Mono-Rails and Telfers**.—In this method a solid iron or steel rail takes the place of the rope, and instead of a traction or haulage rope, the load is generally propelled by means of small electro-motors built into the carriage, and the current is taken from a live cable fixed in close proximity to the rail, and parallel with it.

(d) **Blast Furnace Hoists**, which generally consist of a pair of skips or buckets with wheels running on suitable rails up a sharp incline to the furnace top, the hauling cable raising a full and lowering at the same time an empty skip.

(e) **The Handling of Coke from Coke Ovens**, which includes a great variety of methods of dealing with individual charges from batteries of coke ovens. The choice of method of conveying must depend on the nature of the ground, and the elevation to which the material has to be conveyed.

Fig. 404. Primitive Chinese Ropeway.

History of the Rope.—The rope plays a most important part in three of the above methods of handling, and it may therefore be interesting to explore the history of the rope, as it is obviously, in one form or another, as ancient as rope haulage.

The late Sir Henry Layard, whose discoveries at Nineveh laid bare the daily life of the Assyrians, unearthed in a palace at Nimrod, at the site of Calah, a bas-relief depicting the siege of a castle in the campaign of Tiglath-Pileser III., about B.C. 550. In the carving, Fig. 403, the principal figure is that of a warrior, who is depicted as cutting the rope to which the besieged had attached buckets with which they were attempting to draw water from a source outside the castle wall. The rope ran through a pulley-block, and had evidently a bucket attached to each end, one coming up full, whilst the other went down empty. This bas-relief is about 2,470 years old, and undoubtedly depicts a primitive form of rope haulage. Pulley-blocks, which are also closely connected with all forms of rope haulage, are also of considerable age; they were known to the ancient Egyptians, and in the museum of Leyden may be seen a sheave and pulley-block of Egyptian origin to which great antiquity is assigned. The sheave is of fir wood, and the

block of tamarisk. A portion of the rope found with these relics of an almost prehistoric past has also been preserved. It consists of strands, twisted together, made out of the fibres of the date palm.

So far as is known, the ancients, though they made extensive use of fibre rope, were apparently not much acquainted with wire ropes, which are, of course, an essential feature in modern rope haulage. It is certain that the Assyrians practised the art of beating metal into wire, but there is no evidence to show whether or not they twisted it into ropes. It is said that the Chinese not only knew of, but actually used wire ropes 1,500 years ago, in the form of short ropeways for crossing rivers. The method is shown in Fig. 404. A fine specimen of bronze rope was found in the buried city of Pompeii, and is now preserved in the Museo Borbonico at Naples. Unfortunately no information seems to be available as to the purpose to which this wire rope was applied.

Records concerning wire-drawing, without which wire ropes could not be produced, have been found in ancient chronicles from Augsburg and Nurnberg, dated 1351 and 1360 respectively. At about that date wire was actually drawn through draw-plates. About 1490, one Conrad Celdes writes on the same subject; and in 1500 a certain Richard Archal introduced the wire industry into France, and it was introduced into this country about 1565 by a Saxon named C. Schultze, who, together with one Caleb Bel, started a wire works driven by water-power in the Great Greenfield Valley, Yorkshire, the remains of which, it is said, are still to be seen. The first wire rope works of which there is any record is that of Felten and Guillaume, Cologne, which dates from 1750. This firm did not, however, undertake the manufacture of wire ropes on a commercial basis until 1837. The first wire hauling rope was manufactured in this country by J. Wilson, Derby, for the Haydock Colliery in Lancashire in 1832.¹ Albert of Clausthal—1787-1846—is credited with the invention of the wire rope as it is now made. The first wire ropes of this type were made in 1834.

Wire rope was used in 1821-22, in connection with the Geneva and Freiburg Suspension Bridges; it consisted of wires laid parallel to each other and externally bound together by fine "wire serving," and was known as "Selvagee" rope. The same type of rope was used for other suspension bridges, including also the Brooklyn Bridge, New York, in 1883.

The wire rope mentioned by J. Bucknall Smith, as used in the construction of the old Blackwell Rope Railway, 1838, was an early example of English manufacture. In 1862 a paper on "Wire Rope-Making" was read before the Institute of Mechanical Engineers by C. P. E. Shelley. It might be mentioned that "formed" or "stranded" wire ropes were made on "rope-walks," similar to hemp ropes, and finished on hemp rope machines. Other names associated with the early manufacture of wire ropes are those of Cartwright, and Captain Huddart of Deptford Dockyard.

¹ Considerable doubt exists whether this rope was a stranded or "Selvagee" rope—it was probably the latter.



CHAPTER XXIII

ENDLESS ROPE AND CHAIN HAULAGE

THE principle of this system consists of a rail track on which the trucks are conveyed by means of an endless hauling rope, or sometimes a chain, to which they can be attached and detached at certain points without the necessity of stopping the rope, thus keeping up a constant procession of trucks to or from the workings. The rope or chain generally engages automatically with the tubs or trucks as soon as it comes within reach of them, but disengages as soon as the tubs have reached the higher level, where the rope or chain is raised beyond their reach. The empty tubs are returned on a second pair of rails and are lowered in a similar manner.

Although endless rope and chain haulage is mostly used for relatively short distances, it is equally applicable and frequently used for longer haulages. The difficulty about such installations lies chiefly in carrying the rope over uneven ground. The change of level necessitates, of course, a change in the direction of the rope, and also in deviations from the straight line, where curves have to be negotiated.

The power can be supplied by a stationary engine or electro-motor, either direct or transmitted, or by an ordinary clutch and drum arrangement attached to a line shaft, or finally by the gravity of the material.

The rails are laid on the ground, except where it is essential that the ground space should remain unobstructed, and in such cases they may be raised on more or less lofty structures.

Endless Chain Haulage.—Appliances of this description, running up inclines upon which the trucks are hauled by chains, are principally used in collieries and other mines, and very rarely for long distances. They are often installed for the purpose of raising the trucks to a sufficient height in order to run down again for a longer distance on a gentle downward gradient by gravity.

They are usually termed tub-hauls, or creepers, and consist of an endless chain fitted with claws, or dogs, at intervals of about 12 ft. and having tension adjustment, a pair of chain wheels, main and back shafts, countershaft, driving gear, and channel or angle iron guides. The chains generally used are the "Ley" bushed chains, Nos. 600 and 640, or the "Gaston," Nos. 652 and 662.

A colliery tub is taken up an incline (see Fig. 405) by means of a long link chain with special attachments which engage with the axle of the tub, and thus convey it up the incline. The endless chain travels over two polygon terminals, one of which is fitted with tightening gear. There are many similar devices. The one here illustrated is manufactured by Messrs Coulson & Co. Ltd., of Spennymoor.

Chain Haulage for Hand Trucks.—An endless chain with suitable attachments is used on inclines to assist the labourers to ascend ramps by the chains engaging with the axles of their hand trucks. Such an appliance is in use at the Pequonnock Dock at Bridgeport, Connecticut, U.S.A., and was built by the Remo Inclined Truck Elevator Co., of New York. The endless chain of this device runs in a well-lubricated channel iron 4 in. wide. Fig. 406 shows the arrangement in use, and it will be seen from this

illustration that only the upper strand of the chain projects above the floor level of the ramp. The speed of the chain is about 18 in. per second, so that 960 trucks may be raised per hour. A 5 H.P. electro-motor furnishes the driving power. The installation is used for loading ships with miscellaneous goods, and the incline of the ramp varies with the tide.

Endless Rope Haulage¹ is of far greater importance than chain haulage.

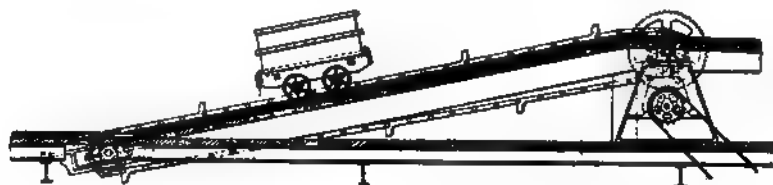


Fig. 405. Example of Chain Haulage for Colliery Tubs.

The speed of haulage depends largely on the state of the running track. A well-laid line with properly constructed onsetting point (where the trucks are joined to the rope) can be worked quite satisfactorily up to a speed of 5 miles an hour, and at that rate 1,000 to 1,200 trucks per hour can be handled. With a rough track which may be laid on spoil banks or tailings dumps, the speed should be reduced to about 2 miles per hour, at which rate trucks can be handled with ease and safety.

Where curve wheels are used to work haulages around corners, a high rate of speed is not desirable, as even with the best constructed track there is always a great deal of wear and tear on both the truck and the rails in negotiating the small curves which the radius of the curve wheels necessitates. The amount of deflection off the straight for a curve wheel should be between 15° and 30°. If the angle at the intersection is too flat the rope is likely to leave the wheel, and, on the other hand, should the angle be too acute, the curve, which by necessity has usually about a 3-ft.

Fig. 406. Chain Haulage for Hand Trucks.

radius, is too sharp for the truck to work around with any degree of safety. This, however, does not apply when a series of wheels guide the rope round curves. As a support to the rope, a roller fitted to a swinging arm should be placed on the on-coming side of the wheel, and as a further precaution against the rope leaving the wheel, the latter should be slightly elevated on the off-going side of the rope.

The gradient to a large extent is limited by the speed of the haulage, as with a fast rope and a steep incline the trucks are likely to "up-end" as soon as hooked, and also

¹ The Author is indebted to Mr H. G. Kay for some of the above data, which appeared in a paper, entitled "Rope Haulage," read before the Chemical, Metallurgical, and Mining Society of South Africa.

at the starting and stopping of the rope. In running inclines a grade of 1 in 8 ($12\frac{1}{2}$ per cent.) is about the limit for a fast travelling haulage, although at a lesser speed inclines 1 in 6 can be worked. The usual method of attaching a truck to the rope of an endless haulage is by means of a "jockey" (see Fig. 407), a V-shaped iron fork fixed to the top of the truck body, into which the rope is forced until the necessary grip is obtained. The form of "jockey" most commonly used in earlier days was bent out of $\frac{1}{2}$ -in. round iron into the form of a V with a long arm projecting downwards from one corner to form a means of attachment to the truck. An improvement on the above is the wrought-iron fan-tail "jockey," made in the shape of a U with the opening slightly tapering towards the base, the jaws also broadened at the top, so that when the truck receives the pull of the rope and the "jockey" turns slightly in its bracket, the slot holding the rope is partly closed up at the top, owing to the overlie of the fan-shaped jaws, thus locking in the rope and tending to prevent it from rising and pulling out of the "jockey."

A very successful "jockey" is constructed with renewable jaws. Fitted to the top of the pillar is an oblong, cast-iron box into which the two jaws are set, these being held in position by means of a wedge driven down between them and through the bottom of the box, this wedge also being held fast by a small wedge and split pin. With this arrangement each jaw can be given a quarter turn when worn, thus allowing the use of four wearing faces before new jaws are required.

In laying a haulage track the rail on the side to which the "jockey" points must be slightly elevated, so that the rope is brought directly over the centre line between the two rails, and to prevent unnecessary wear and tear on the rope, rollers or hard wood rubbing blocks are placed at intervals between the rails to carry the sagging rope.

A most important item in the haulage is a properly constructed onsetting point. The grade feeding the trucks to the onsetter should be such that when the truck reaches the rope for hooking, the speed of the rope and truck are exactly the same. Should the speed of the truck be either greater or less than the speed of the rope, a sudden jerk will take place on hooking, which is very detrimental to the life of the rope.

At a fast feeding onset, brakes should be used to regulate the run in of the trucks, also a contrivance to turn the "jockeys" automatically into the right position for hooking; and as a further safeguard against the trucks leaving the rails at the point of hooking, check rails should be placed for a short distance on each side of the onsetting point. The catenary curve connecting the down grade to the onset with the up grade of the incline requires special attention in laying out, as upon this the rate of hooking largely depends. The rails must follow a line which is parallel to the natural curve taken up by the rope, and to maintain the rope permanently in this position a weight or other tension device is employed. This device, with its frame, also takes up the expansion or contraction in the rope due to stretch or change of temperature. A well-balanced and sensitive rope is absolutely essential to the fast-feeding haulage.

At the point of disengaging the trucks an "apex" is formed with a down grade sufficiently steep to cause the truck to overrun the rope, and this change from a pull to a push on the rope causes the "jockey" to come square with the rope and easily free itself. On a long steep incline, or, in fact, on any haulage which is at all permanent, automatic disengaging frames should be used in order to dispense with labour. The frames are made in various ways. A cheap and effective one is in the form of a double cross frame carrying two long timber runners (see Fig. 408) placed parallel to the track,

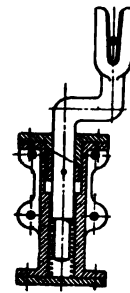


Fig. 407. Rope Clip or Jockey used in connection with Rope Haulage.

and just sufficiently high to clear the top of the truck body. Fixed high up and between these runners, and at the off-going end, is a bar with a roller carrying the rope; and as the truck reaches the frame the body is slightly raised until it comes into contact with the runners, when the rope is pulled out of the "jockey" and the truck released automatically from the rope.

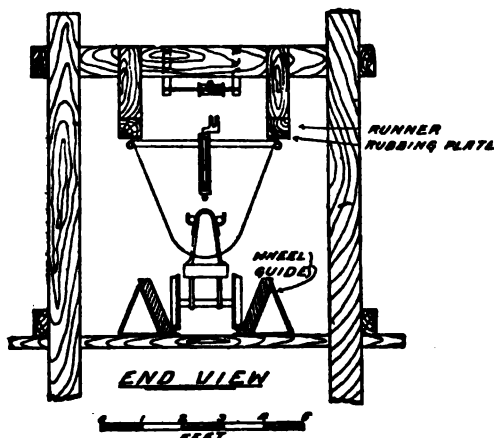


Fig. 408. Automatic Disengaging Gear for Rope Haulage.

of the truck carriage, instead of on to the body, as is the usual practice. With this arrangement the truck can be tipped without being released from the rope, and consequently there is no time or labour lost in disengaging or rehooking. A haulage of this description is very economical, as, from the time the truck is filled at the bin, and hooked to the rope, there is no need to handle it until it is returned to the filling bin again, the tipping, righting, and disengaging operations all being automatic. With this arrangement trucks negotiate curves of 12-ft. radius by a series of rollers set about 2 ft. 6 in. apart, and just on a level with the "jockey" on the truck. These curve frames (see Fig. 409) are held in position by ballasting them down with sand bags or stones; they can thus be easily shifted bodily forward as the dump extends.

A serviceable truck tipper (see Figs. 410 and 411) consists of a frame carrying a length of rail or pipe set at a height to just catch the top of the truck body. This tipping bar is placed diagonally across the track with the on-coming end, about 1 ft. outside the rails, and the off-going end over the centre line of the track. As the truck reaches the tipping bar, the body runs along it, and is pushed over to one side until it is over-balanced and tipped,¹ a check bar being placed over the truck wheels to prevent the carriage capsizing also. The same principle is applied to the "truck righter." A

¹ For descriptions of other self-emptying trucks, sometimes employed on such lines, see Chapter XXXIV., "Unloading by means of Specially Constructed Self-emptying Hopper Wagons."

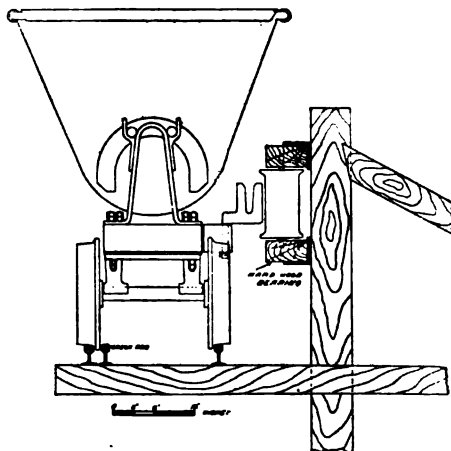
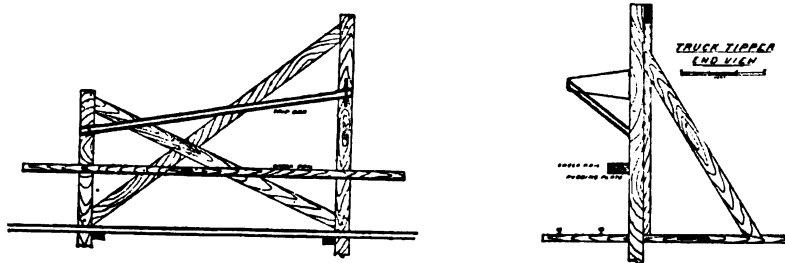


Fig. 409. Side Roller for Negotiating Curves.

length of rail or pipe is bent obliquely and set alongside the track, so that the lower end of the incline will just catch under the down-turned lip of the truck body, and as the truck is drawn along the incline, the body is raised automatically until it regains its upright position (see Fig. 412).

At the Premier Diamond Mines endless rope haulages are used throughout the workings. The main haulage of one installation has three changes of grade, the steepest being 1 in 8, or $12\frac{1}{2}$ per cent. The tracks are laid with 40-lb. rails set on wooden sleepers, width between up and down tracks, 6 ft. The rope is of plough steel, $1\frac{1}{4}$ in. diameter, travelling about $4\frac{1}{2}$ miles per hour. The rate of hooking on this haulage is from 1,000 to 1,200 truck loads per hour, although over 26,000 loads have been hauled in a working



Figs. 410 and 411. Automatic Truck Tippers.

day of twenty-one hours, and over 140,000 loads in the week. The length of incline from onset to apex is 3,123 ft., and the vertical lift 239 ft.

Another haulage plant at the same mine has two changes of grade, 1 in 8.9 (11.2 per cent.) and 1 in 8 ($12\frac{1}{2}$ per cent.) respectively. The tracks are also laid with 40-lb. rails, 8-ft. centres between tracks; the rope is the same, travels at about the same rate, and has the same capacity as the previous haulage referred to. The length of incline is 2,425 ft., and the vertical lift 270 ft.

Fig. 413 represents an appliance for the same purpose as Fig. 405, in which the tubs are conveyed uphill by ropes, which engage with the "jockey" at the top of the tub instead of with the axle as in the preceding drawing. It also shows the two terminals with the driving gear, and the tightening arrangement at the lower terminus by means of a weight.

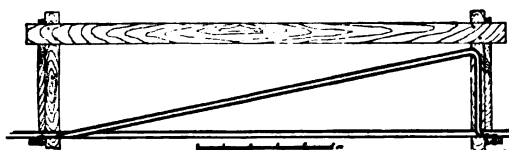


Fig. 412. Automatic Truck Righter.

Other Examples of Rope Haulage, where, however, the rope engages with the lower part of the trucks, are represented in Figs. 414 and 415. They show one method employed by Bullivant & Co. for detaching a truck from the hauling rope. The detacher, which is fixed upon the sleepers, automatically uncouples a clip on the rope, when the lever of the clip strikes against the detacher. Figs. 416 and 417 show the same clip fitted with a connecting rod and draw-bar with springs, to reduce the shock which may take place in attaching the clip to the rope. The head of the clip is fitted with two springs which connect to a bracket attached to the truck as shown. When the clip is released by the automatic detacher (see Figs. 414 and 415), or by hand, the springs lift the clip clear of the rails, as shown in Figs. 416 and 417,

thus allowing the detached trucks to pass over cross-overs. Another form of coupling suitable for light loads is shown in Fig. 418. This is not unlike the "jockey" described previously. This clip can be arranged to automatically detach itself from the rope by the following method: The sheave shown is raised above the centre line of the rope, so that as the clip approaches the sheave the rope is lifted clear of and thus detached from the clip, which latter is turned out of the way by striking the sheave. When connecting to the rope, the clip must be turned back. A sheave, as described, is placed in a suitable position for the rope to drop from the sheave into the clip.

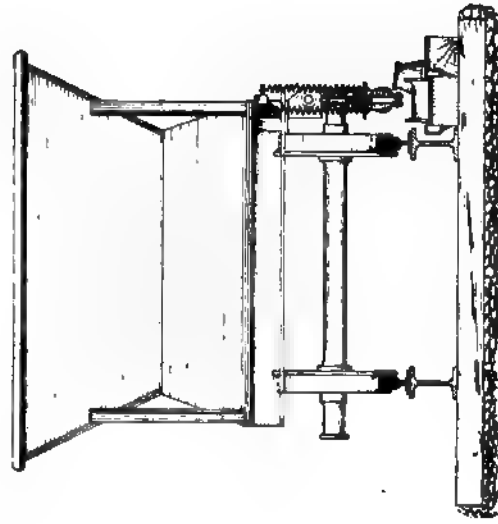
An automatic rope haulage plant, built by Bullivant & Co., fitted with brake gear, is shown in Figs. 419 and 420. The loaded trucks are brought to the top of the incline and attached to the rope on the left-hand track (when looking down the incline); the rope passes to the brake gear and thence to a turn-round or terminal wheel and back along the right-hand track (looking down incline), and down to the bottom of the incline, a distance of about 4,000 ft.; here the empty trucks are attached to the rope.

A capstan is used for conveying the full trucks to the top of the incline, and here, after being connected to the rope, they descend, thereby generating a considerable amount of power which is used for working an air compressor connected to the brake gear by a train of gear wheels. The air from the compressor is stored in a receiver, which is shown on the top of the engine-house, and this receiver communicates by pipes with the capstans on the top and bottom of the incline, which are used for marshalling trucks. The whole of the winding gear and compressor plant is controlled by levers located on the platform of the control tower, from which a man has the whole incline under his observation.

After the full trucks have been detached from the rope on the left-hand track at the bottom of the incline, the empty trucks are attached to this rope, and at the same time those at the top of the incline, on the right-hand track, are replaced by full ones. When this has been completed, the order is reversed and the full load this time moves down, on the right-hand track, hauling up the empties on the left-hand one.

A truck haulage installation, also by Bullivant & Co., erected on a pier, is shown in Figs. 421 and 422. In this arrangement it will be seen that the haulage rope passes down the inside of the tracks (that is between the two rail tracks) until it comes to the cross-overs. Here it dips down below the pier level, round two sheaves to the outside of the track, in which position it continues till the cross-over is passed, when it returns *via* two other rollers to the position between the tracks again. The return of the rope is effected in

Fig. 413. Example of Rope or Chain Haulage for Narrow Gauge Railways.



Figs. 414 and 415 Automatic Truck Uncoupling Device.

Figs. 416 and 417. Automatic Truck Uncoupling Device.

a similar manner on the other side. With this arrangement the clip is attached to the rope and a truck hauled along until within a short distance of the cross-over. Here the clip is disconnected and attached to the rope outside the track to pass the cross-over, when the clip is again attached to the rope on the inside of the track. The power for driving this plant is supplied by a steam-driven winding engine, and the rope is kept taut by a live tension weight. By a winding tackle this weight is kept in the position shown on drawing, at any point between the pier and water level.

An interesting arrangement of canal haulage, for drawing boats through a tunnel, is shown in Figs. 423 and 424, although it does not come strictly under Endless Rope Haulage. By the system here employed, a rope, after passing the drum of the winding engine in the haulage boat, rests in the canal bed, the ends being connected with suitable anchorage, provided with tension gear to take up any slack. The winding gear in the haulage barge is electrically driven, the current being supplied from an accumulator boat which is drawn behind. When the motor is started the boat hauls itself along the fixed rope. With this installation a train of barges may at one time be drawn through the tunnel at a speed of from two to three miles per hour.

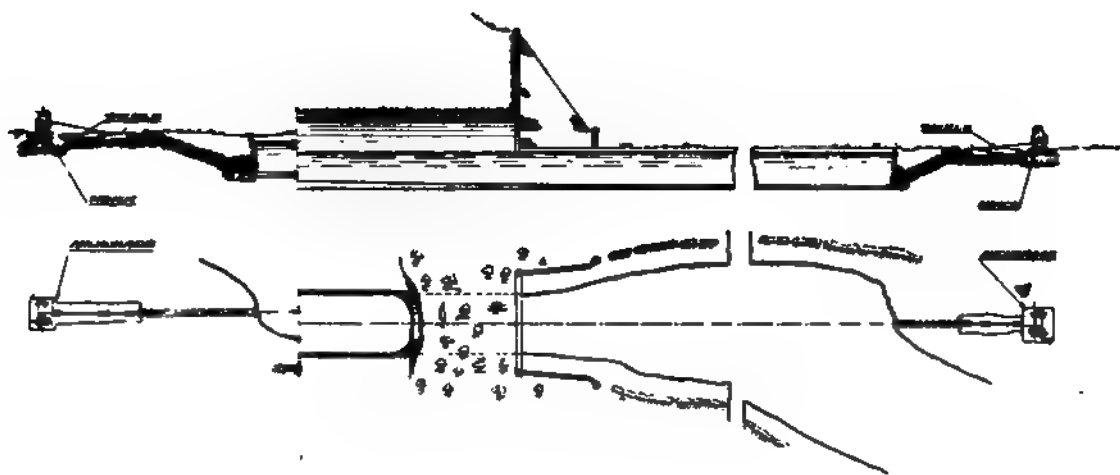
As an interesting example, the rope haulage plant erected by Georg Heckel, at the Röchling Iron and Steel Works at Völklingen, in the district of Saarbrücken, and illustrated in Figs. 425 to 433, may be mentioned. The arrangement there is as follows :—

The haulage plant commences in close proximity to the coal-washing plant, where the driving gear and the steam engine are also situated. There

Fig. 418. "Jockey" Coupling below Truck.

are two lines of rails, one of which is for loaded trucks and the other for empty ones on their return journey. The trucks or tubs are loaded from the bin A, which receives the washed coal. When full, they are run on to the right-hand track of rails, and the rope is pushed into a clip or jockey attached to the front of each tub (see Fig. 407). By the traction of the rope, the clip engages firmly as the fork turns on its axis and adjusts itself to the rope, and the truck is then carried along. The distance of travel is 264 ft., while the angles negotiated are as much as 90°, and the inclines as much as 10°. After a sharp incline, the tubs turn round at the terminus B, and descend upon the second line. Before reaching the lower terminus the rope is so raised that it automatically disengages itself from the clips. The trucks discharge themselves automatically. Fig. 428 represents one of the tubs, the two sides *a*, *a* being so hinged to the upper portion of the frame that the flap doors open outward. The bottom of the tub has a ridge in the middle and slopes from there towards the flap doors, thus ensuring a complete discharge of the tub when these doors are opened.

Beneath the body of the truck is fitted a powerful spring which depresses the two levers *b*, and thus keeps the door closed. At the end of each of these levers *b* there is a latch which overlaps the side of the truck. Another lever *c* is fitted underneath the truck which carries at its end a roller. This is for the purpose of compressing the spring



nnel.

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Figs. 419 and 420. Automatic Rope Haulage Plant fitted with Brake Gear.

as soon as the roller comes in contact with any obstruction on the line. By the compression of the spring, caused by such obstruction, the two levers which hold the sides of the truck are released, and thus allow the latter to open outwards. The unloading contrivance consists of a short inclined plane *d* made of flat iron (Fig. 427), which is fitted in the middle between the lines of rails, at the point where the trucks are to be unloaded, and in this way the discharge of the coal is effected at any one of the three destinations.

The closing of the side doors of the trucks is also effected automatically. For this purpose immediately beyond each delivery point there are fitted on both sides of the track oblique rails *e* (Fig. 429), at the height of the lower edge of the movable sides *a*, *a* of the truck, and at the end of these rails are fitted two rollers with powerful springs. As the truck passes with open doors, the rails *e* gently close the doors by pressing them behind the levers *b*.

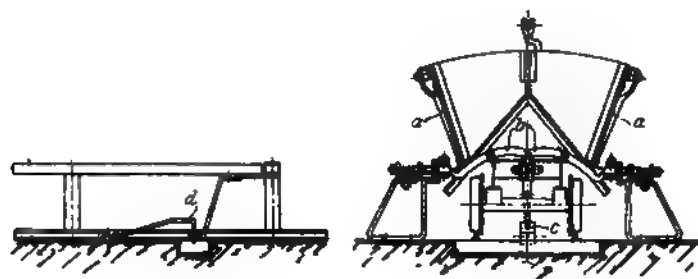


Figs. 425 and 426. Rope Haulage Plant at the Röchling Iron and Steel Works, Völklingen, Saarbrücken.

In consequence of the sharp curves to be negotiated, the tubs are kept rather short, and the distance between the axles is such that it is not possible for the back wheels to be lifted off the rails by any pressure of the rope on the clip which is fitted to the front. The tubs are entirely of iron, and weigh over 13 cwt., having a capacity of about $17\frac{3}{4}$ cwt.

The ropes are driven at the rate of 100 ft. per minute by a double-grooved pulley connected by suitable gearing to a small steam engine. From this driving pulley the rope passes over two guide pulleys in a downward and upward direction. At the bottom of the loop thus formed is another guide pulley, which is weighted for the purpose of tightening the rope, which then passes to the commencement of the track, where there are two more guide pulleys, one of which guides the full rope, while the other guides the return rope. With the exception of the wheels supporting the return run, all the pulleys are grooved and lined with leather, which is stamped out in small pieces, which stand on end and form grooves in the bottom of these rope pulleys. This arrangement has been found to effectually prevent any slipping of the rope.

The use of forked clips for engaging the trucks necessitates the rope running at all times at an equal distance above the line of rails. To ensure this, at those points where the inclination of the track alters, special guide pulleys are used. These consist of a series of rollers fitted round the circumference of a revolving disc. The spaces between the rollers will accommodate the clips on the trucks. Vertical sheaves have been used, and the ropes are also guided in a lateral direction by a similar contrivance. In order to meet sharp curves in the track, channel irons have been used in place of the ordinary rails. These have been bent to the correct curve, and the sections are of dimensions which will allow sufficient play for the wheels in the groove (see Figs. 430 and 431). Special sections of rail are used to join up the channel iron to the rails, in order to gently guide the wheels from one section to another. Otherwise the illustrations explain themselves.

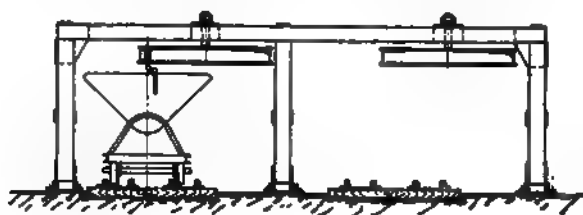


Figs. 427 to 429. Automatic Trucks in connection with Rope Haulage Plant.

In order to prevent interference with the traffic by a runaway tub which might become disengaged, stops are placed upon the inclined portions of the track, suitable for trucks travelling uphill, as well as for those moving in a downhill direction. Figs. 432 and 433 represent these appliances. The stop for tubs travelling in an upward direction consists of two levers which are fitted side by side between the rails, and are coupled together by a horizontal spindle round which they can rotate in the direction of the haulage. The axle is situated beneath the track, while the upright arms project above it (see illustration). In this position they are maintained by a weight. As the truck ascends the line, the axles of the wheels press the upright levers forward, and the truck passes over them without hindrance. Should the tub, however, by some accident, become detached, the levers catch and stop the descent because they do not admit of any backward movement. The shock to which the upright levers would be exposed under these circumstances is lessened by a powerful volute spring.

The appliance for the descending truck is as follows: At certain distances from each other two pairs of levers, similar in construction to those just described, are fitted to

the track. These levers are coupled together beneath the line so that both pairs must move together. Fig. 433 shows the levers in both positions, one being in full and the other in dotted lines. It will be seen that they stand at a certain angle to each other. Their action is as follows: As the truck descends, the axles of the wheels depress the short levers, and thus raise the longer and lower levers in an upright position standing at right angles to the track. As soon as the tub has left the first levers, these will swing back to their original position, and thus pull down the long lever for the tub to pass over unhindered. Should, however, the tub descend at an unusual speed, as would be the case if a truck became disengaged, it would reach the lower levers before they had



time to descend and thus stop the tub, the shock being again taken by a powerful volute spring. The distance between the two pairs of levers must always be accurately adjusted to the size of the tubs and their normal speed.

The driving gear of a similar installation built by the same designer, and for the same firm, is shown in Figs. 434 and 435. This plant is for handling 150 tons of iron ore per hour, but is capable of dealing with 300 to 360 tons. The driving gear is actuated by an electro-motor, and the rope pulleys are between 12 and 13 ft. in diameter. The driving power from the motor is reduced by three pairs of spur gear, giving the rope a travel of 200 ft. per minute. After the rope has passed over the two main pulleys A and B, it is conducted over a horizontal pulley C, which is mounted on a carriage and connected with a weight

Figs. 430 and 431. Angle Station of Rope Haulage Plant.

which is suspended on a chain from a tower built for the purpose. This is necessary in order to take up the stretch of the rope, which is 32,800 ft. long. The rope itself is $\frac{1}{8}$ in. in diameter, and has a breaking strain of 29 tons, but it is only strained during the ordinary working to a load of 4 tons. The trucks are put on the lines at a pitch of about 35 to 40 yds. Each truck holds $1\frac{1}{2}$ tons of ore, and the incline of the line is very slight.

Further interesting examples of rope haulage¹ are found at Düdelingen, Lorraine, for handling the iron ores from the Minette mining districts, one of the principal sources of iron ore in Central Europe. The ore deposits are so situated that they have to be got through a drift in the side of the mountains. In the older installation it was the

¹ From an article by Fr. Tillmann, *Zeitschrift des Vereins deutscher Ingenieure*, 12th March 1910.

practice when using rope haulage to convey the ordinary mining trucks to a raised position on the bank, and there transfer their contents into self-emptying trucks, which were then taken by a second haulage installation to the ore pockets. It is obvious that this

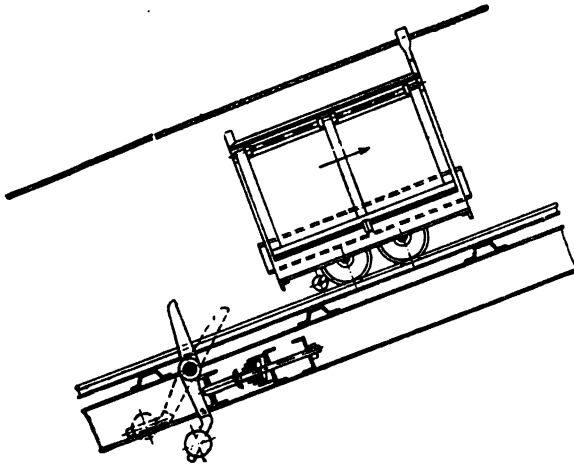


Fig. 432. Stops Built for Tubs Travelling in an Upward Direction.

method could be much simplified by the adoption of one haulage system, thus obviating transference of the load, but this would only be possible by the use of self-emptying trucks in the mine, conveyed all the way by the one system. This was done at D dellingen, and the installation has been successfully at work since 1908. The mining authorities were rather reluctant to adopt this system, owing to the danger of the self-emptying trucks discharging their loads on the inclines underground, but the construction of the trucks makes such an accident almost impossible. The installation handles the material in one unbroken operation

from the face to the pockets. There is also a second haulage plant on similar lines, which takes the ore from the ore pockets to the blast furnace of the same company, a distance of $2\frac{1}{2}$ km., say 2 miles away.

The self-unloaders used on this line are shown in Figs. 436 and 437, built on the Heckel principle. Their capacity is about 2 tons of ore, and the weight of the trucks is nearly 1 ton. The wheels are of cast steel and fitted with roller bearings. The illustration shows the other details of construction. The opening of the side doors calls, however, for some little further description. The two doors are held closed by the catches *a*, and are opened by the lever *b*, which, in order to release the catches *a*, must make a downward movement (a similar catch with an upward movement might release the load by coming in contact with a piece of ore lying between the rails). The apparatus acts as follows: A pair of channel rails *c* are fixed in the centre of the track hinged at one end and raised at the other, but if not in use the raised portion can be lowered to bring it out of action. As the truck approaches these channel rails *c*, a double pin in lever *b* engages with them and forces lever *b* down, thereby releasing the doors. The ore pocket with its approach is shown in Fig. 438. It is 330 ft. long, and has a capacity of 1,000 tons

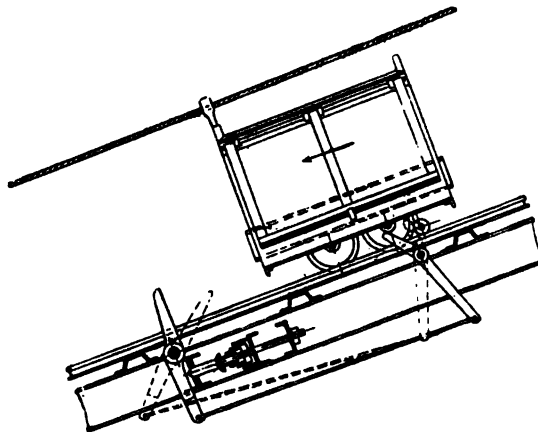


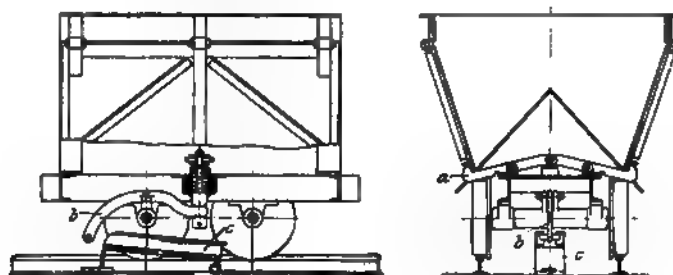
Fig. 433. Stop for Tubs Travelling in a Downward Direction.

of ore. The haulage rope is elevated above the track, and the trucks ascend a gentle incline, as shown on the right hand side of the illustration; they then negotiate a curve of about 180°, and land on the level above the ore pocket. The trucks then pass through this building, dump, and descend empty on the other side to the bottom of the



Figs. 434 and 435. Driving Gear for Rope Haulage Plant.

mine, as shown in the upper left-hand corner. Fig. 439 illustrates three of the trucks on the haulage rope above the ore pockets, the first one being at the point of discharging. It will be seen from this illustration that a number of trucks are coupled together, whilst the two ends of the train so formed are clamped at both ends to the haulage rope. This is for the purpose of preventing the running forward or backward when negotiating inclines; that is to say, if the train goes up hill the front chain will be tight, and if it



Figs. 436 and 437. Automatic Self-Unloading Trucks for Rope Haulage Plant.

goes down hill the back chain will be tight. Two of the trippers, *c*, before mentioned, are shown in this illustration. The bar screens above the ore pockets are for the purpose of letting small material through, whilst the large pieces are fed on to a grinding machine and reduced (see Fig. 443). Another view of the same is shown in Fig. 440, with an approaching train and a number of trippers *c*, any one of which can be made to engage,

Fig. 438. Rope Haulage Plant in Connection with Ore Pocket.

Fig. 439. Rope Haulage Trucks Discharging into Ore Pockets.

Fig. 440. Rope Haulage over Ore Pockets.

and thus unload the train in any position. The method by which the doors are automatically closed after the trucks have been discharged and before they return to the mine to be reloaded is shown in Fig. 441. A train passing a curve and the eight pairs of guide wheels which lead the rope round the curve can be clearly seen in Fig. 442; there

Fig. 441. Arrangement for Automatically Closing Doors of Rope Haulage Trucks.

are forty such wheels to conduct the rope round the various curves. These wheels are 5 ft. in diameter, and of cast steel, the grooves in them being sufficiently deep for the hauling attachment on the ropes to be accommodated. A cross-section through the ore pocket, showing also the three lines of rails beneath for drawing the ore from the pocket and conveying it from there to the furnace, is given in Fig. 443.

Fig. 442. Rope Haulage Train Negotiating a Curve.

The haulage plant was erected for 1,800 trucks and over 3,000 tons of ore in ten hours. The speed of the hauling rope is 150 ft. per minute, and the distance between the terminals is slightly over 1,000 yds., but it is intended to extend it to 2,000 yds. Owing to the incline of the drift, a motor of 250 H.P. was necessary. In the second installation the distance from the ore pockets to the blast furnace is 2,500 yds., and owing to the more level road, a motor of only 180 H.P. sufficed.

A rope haulage plant of an unusual design is that of the Soc. Anonyme des Hauts Fourneaux & Fonderie de Pont-a-Mousson, France.

This is for handling 180 tons per hour of iron ore. The most interesting portion is

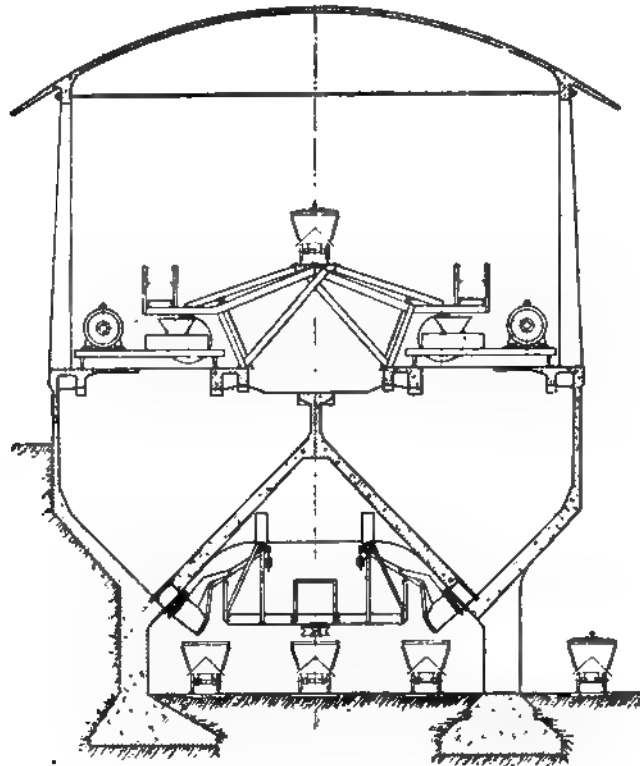


Fig. 443. Section through Ore Pocket showing Rope Haulage Plant.

a movable bridge running on a rail track on each side, and commanding the whole of an extensive ore pocket; the position of the bridge can be changed while the haulage plant is in motion. The self-unloading trucks hold $1\frac{1}{2}$ tons of ore each, whilst their weight is approximately 1 ton each. The haulage rope (Glinz Patent) is composed of chain and rope; the lengths of rope units are about 12 yds., and they are coupled to each succeeding length by a short piece of chain. A portion of this compound chain and cable is illustrated in Fig. 444. The trucks are attached to the cable chain by the usual "jockey," the chain portion being dropped on to this. A plan is shown (Fig. 445), and the endless cable is indicated by dotted lines, the arrows showing the direction of its travel. The ore, as it comes from the mine in trucks, is dumped by two tips B into a small hopper, the



Fig. 444. Compound Chain and Cable Haulage Rope.

empty trucks being raised sufficiently by the chain haulage *c* to return by their own gravity to the pit mouth. Beneath the small hopper just mentioned the self-unloaders for the haulage plant are filled. The trucks are then attached and ascend an incline of 20° , and by the time point *D* is reached they are on a level with the top of the ore pockets. The trucks are then led from their own track on to the bridge, where they are emptied and return again to the starting point, following the track shown by dotted lines and arrows. The bridge is manipulated by one man, who has his seat in a cab, which is shown in Fig. 445 on one side of the bridge. The installation is fitted with safety appliances to prevent any trucks running away on the inclines. The speed of the cable chain is 100 ft. per minute, and with a truck every 12 yds., or 150 trucks per hour, is equal to 225 tons' capacity. The driving power is provided by a 20 H.P. motor, and one of 10 H.P. for manipulating the bridge.

Fig. 445. Plan of Rope Haulage Plant of the Soc. Anonyme des Hauts Fourneaux & Fonderie de Pont-a-Mousson, France.

Fig. 446. Cross-Section through Ore Bunker showing the Bridge.



CHAPTER XXIV

AERIAL ROPEWAYS

MODERN industry has made the widest use of aerial transportation, as that method of handling material is termed which consists of conveying buckets or skips on ropes, such buckets being filled with the material to be handled, and being automatically or otherwise discharged. In this and the two following chapters is given a succinct description of all the principal systems of rope and cable haulage, with some account of the various purposes to which ropeways and aerial cableways are applied.

Aerial rope transportation may be divided into three classes¹ :—

A. Aerial Ropeways for Conveying Purposes Only.

B. Cableways, which Convey and Hoist the Material at the Same Time (see Chapter XXV.).

C. Appliances for Coaling at Sea (see Chapter XXVI.).

The origin of ropeways is, like that of many other flourishing institutions, lost in the mists of antiquity; but it seems quite possible that this means of transporting material was practised by the ancients, who had made more progress in engineering than they are often credited with. It may be objected that little or no traces remain of these ropeways, if ever they existed. It must be borne in mind, however, that then, as now, ropeways were often essentially transitory works, erected for special purposes, and bound to disappear as soon as the needs that called them into existence had passed away. Moreover, ropes are not objects that are calculated to defy the ravages of time, especially fibre ropes which must have been used in antiquity.

A curious old print (see Fig. 447) gives a graphic delineation of a ropeway that was erected by a Dutch engineer, Adam Wybe, of Harlingen, for the city of Dantzic in 1644.

This ropeway connected the city ramparts with a hill outside the town known as the Bischoffsberg. A single endless rope was passed over pulleys suspended on high posts, two of which were embedded in the city moat. The rope carried a number of rather diminutive buckets, which were filled with earth on the hill, and were discharged at a certain point on the ramparts, probably for the strengthening of the fortifications. The empty buckets were returned to the starting point on the same rope, which ran back on another line of posts. This was simply an endless rope running between two not very distant points.

The modern ropeway may be said to date from the adoption of wire ropes. It is a

¹ During the litigation, *Ropeways Ltd. v. Hoyle*, and the trying of the case before Judge Petersen, May 1919, some confusion arose concerning the definition of a rope and a cableway. The principal makers of these devices have, in consequence, decided that :—

“An aerial ropeway is an appliance for conveying materials between two or more points, where steel wire ropes elevated above ground level on trestles are employed both for supporting and hauling along the loads which are contained in carriers or receptacles of a suitable nature.

“An aerial cableway or blondin is an appliance for conveying a load and for hoisting and lowering it by means of steel wire ropes at any point between its terminal towers, performing, in other words, the functions of a crane, but having a greater radius of action. These plants usually are built having one span only, but can have more by the introduction of suitable intermediate supports.”

remarkable fact that, although as already stated, wire ropes were known to the Romans eighteen centuries ago, they were not, with a few exceptions, pressed into the service of modern engineering till the nineteenth century was well advanced.

The first English patent for ropeways was granted to one Henry Robinson, of Seattle, in the county of Yorkshire, 27th January 1857. The writer has not, however, been able to find any trace of an installation erected on the system. Although the first patent was taken out by Robinson, credit for such is generally given to Charles Hodgson, whose patent dates from the 20th July 1868. His claims included both the double and single

Fig. 447. An Early Ropeway erected for the City of Dantzic.

systems. The Continental pioneers were Theobald Obach, 1870, and Adolf Bleichert, 1873, and on these inventions most of the modern ropeways are more or less founded.

As far as the author has been able to ascertain, the first ropeway of any note erected on the single rope system was built in the year 1860, in the Hartz Mountains, by Baron F. F. von Dücker. The first ropeway on the double rope system, that is to say, with hauling rope and rail rope, was also built by him between the years 1868 and 1870. For the further development in the early stages we are indebted to Kremer, Bleichert, and Otto, who in 1874 made these conveyors a practical success.

An inherent advantage of overhead rope haulage is, that it may be worked over ground which would be impracticable for a tram or railway, except at a prohibitive cost for such items as embankments, cuttings, and tunnels. Indeed, it may be said that in traversing rough or mountainous ground the methods of ropeway and railway engineers

are diametrically opposed, for whereas the one in laying out the line seeks easy grades, to avoid as far as possible irregularities, the other ignores, as a rule, the conditions of the ground, and follows a bee-line from point to point. Up and down gradients which balance each other may be ignored, and the necessary driving power can be arrived at by taking the mean gradient between the terminal points.

In cases where the mean gradient is in favour of the load, the ropeway may become self-acting, and under certain conditions may even develop surplus energy. The ideal ropeway should go in a straight line from point to point, the rope being supported wherever the ground lends itself to the erection of standards, which should not be raised higher than necessary. With regard to the height of standards, however, the engineer is necessarily limited by the ground. It may be noted that since so many engineers of eminence devoted themselves to the building of ropeways, great improvements have been made in the details of construction, and in particular the high trestles which were so marked a feature of the earlier ropeways have to a great extent been superseded. It is probable, too, that the power used in working ropeways has been very considerably reduced by the selection of suitable gradients in favour of the load. It is further contended that ropeways are independent of weather conditions, and this is no doubt true to a certain extent, because in a mountainous country a heavy fall of snow, which would stop the working of a tramway, would rarely interfere with the working of a ropeway. But it is a question if even the best constructed ropeway can always be worked in high winds and gales, though on this point experts differ. It is usual, however, to protect dwellings and thoroughfares over which ropeways pass by guards or safety nets.

Ropeways¹ have undoubtedly the advantage of simplicity of construction, and should not under ordinary conditions be subject to interruptions from the gear getting out of order, though of course ordinary care must be exercised by the staff, which need not be extensive. Beyond one competent engineer to superintend the working of the line, unskilled labour should suffice. The power required is relatively small, and under some conditions no driving power at all is required. In many cases, however, the ropeway erector must take into consideration the capital that may be absorbed by "wayleaves," because unless the ropeway is run entirely over his own ground he will be compelled to come to some arrangement with the proprietors of the land over which the ropeway will pass. This is termed a "wayleave."

It is understood that on the Continent landowners are not generally over exacting with regard to "wayleaves," but in this country the reverse is unfortunately the case. More than one ropeway system which might have rendered good service has had to be abandoned because of the excessive value placed by landowners on the "wayleaves" they were asked to grant. This is the more regrettable as the ropeway interferes little, if at all, with the land over which it passes. The amount of ground required for the supports is so trifling as to be practically a negligible quantity, while the line itself in no way interferes with the cultivation of the ground underneath.

It may be stated that the prime cost and working expenses of ropeways are relatively moderate. Of course, the manufacturer who intends to put up a ropeway should estimate exactly what work it will have to do, so as to proportion his outlay to the useful effect he desires. The working expenses should be moderate, as even extensive ropeways require but a small working staff. The cost of repairs and upkeep must necessarily be considered, but good material, sound workmanship, and above all suitable construction, will, in this as in other cases, reduce expenses to a minimum.

¹ The Author is indebted to the late Mr W. T. H. Carrington, M.I.C.E., for portions of the following description.

Ropeways have their limitations ; and although they can be carried over the most difficult ground if in straight lines, curves considerably increase their expense and working cost, necessitating as they do the erection of angle stations.

The modern system dates back little more than three or four decades, but during this period the distances which can be traversed and the loads which can be carried have undergone remarkable developments.

The form of ropeway adopted will no doubt vary widely according to the nature of the ground and the work required to be done. In the same way details of construction, such as the kind of material for the supports, will depend more or less on local conditions. In some cases wooden supports may be found quite sufficient, while in others structural steel may be preferable ; ferro-concrete even is sometimes used.

Ropeways are very frequently employed for conveying timber from distant forests remote from navigable waterways. In mountainous and roadless tracts of land the conditions are such that the stately tree must either remain in its native forest, or if it is to serve man's purpose, it must be brought forth over gorges and ravines by the only possible conveyor for such a purpose—the Ropeway.

Ropeways may broadly be divided into two grand divisions, namely, *Single* and *Double*. In the first case the load to be moved is suspended from an endless running rope forming the ropeway ; in the second, from a traveller or runner drawn along a fixed rope by a separate traction rope commonly known as the hauler.

The subdivisions of these two main types are many, and are due to diverse conditions as regards ground and the load under which they have to work.

The Single Ropeway.—This system is the oldest and simplest, and in its most primitive form has already been mentioned as the one erected for the city of Dantzic in the middle of the seventeenth century.

In this system one endless running rope is used, supported upon a number of roller supports carried upon trestles or standards. The rope passes at one terminal round a driving drum from 6 to 10 ft. in diameter, which gives the motion to the rope at a rate of speed of from 3 to 4 miles per hour ; the other terminal is similar, but instead of giving motion it keeps the rope taut by a suitable tightening gear. The loads are carried in receptacles fitted with simple curved hangers pivoted in a Λ -shaped saddle, which holds sufficiently tight by frictional contact to the rope, and therefore travels with the same. The suspended frame of the load carrier is also fitted by the side of the Λ -shaped saddle, with the small grooved pulley which engages at the terminals with shunt rails, and thus disengages itself from the running rope, and becomes stationary on these shunt rails for filling or emptying, after which it is pushed on to the returning rope.

It is generally considered that the single ropeway is more suitable for relatively short distances and moderate weights, and where the inclines to be negotiated do not exceed 1 in 3, nor the individual loads 5 to 10 cwt. Also individual spans greater than 200 to 300 ft. should be avoided, unless on very broken ground or over deep valleys where they are unavoidable. We shall see, however, in the succeeding pages that experts, who devoted their energy almost exclusively to single ropeway designs, have achieved much better results than the above, and that they do not hesitate to apply the single rope system to practically any conditions and capacities capable of being handled by ropeway.

From the foregoing we have seen the extreme simplicity of the single ropeway, and will now go a little more closely into the details already outlined. An endless wire rope runs round two terminal wheels or drums, the said rope being supported between these drums on suitable pulleys, the diameters of which vary according to the size of the rope. These pulleys are carried on posts or supports of iron or timber at a sufficient height to enable

the carriers (as the skips or other receptacles in which the material is conveyed are termed) to clear all obstacles, even when the rope is slack. These carriers hang from the travelling rope and pass unobstructed over supporting pulleys, being suspended by curved hangers, pivoting in the A-shaped saddle which rests on the rope. The saddle consists of an iron frame, fitted with friction blocks of wood, rubber, or composition, to cause sufficient adherence to the rope, and to enable the carrier to pass with the rope up inclines and over the pulleys. The box carrying these friction blocks is usually made of malleable cast iron, and is provided with wings at each side which, as the carrier arrives at the supporting pulley, embrace or pass between the flanges of the pulley rim, when passing over the same. The box is, further, fitted with two small wheels known as shunt wheels. Their function is to remove the carrier from the rope when the latter negotiates terminals or curves, where shunt rails are placed. It should be pointed out that the ropeway is on a slightly higher level than the rail, and that the on and off running ends are bent downward so that the load transfers itself on and off them gently by its own velocity. These rails are so fixed that when the carrier approaches them the small wheels engage with them and lift the saddle from the rope, enabling it to pass to where the loading or unloading is required to be done, or round the curve wheels. The impetus derived from the speed of the rope (which averages 4 miles an hour) is sufficient to enable the carrier to automatically clear itself from the rope. This form of ropeway consists, therefore, of one endless wire rope driven by suitable gearing, and supporting carriers which travel with it either by means of friction or mechanical clips.

A modification of this form of ropeway, or rather its prototype, is one in which, though rarely used, the carriers hang from and move with a single rope, being permanently fixed to it. This system is recommended for routes on which steep inclines and sudden changes of level occur, and where guide or depressing pulleys may be necessary, which would obstruct the passage of the carriers of the friction contact type. Although this form of ropeway is similar in all such respects as driving and tightening gear and pulleys to the first-mentioned system, there is this important difference, that the carrier does not rest on the rope, but is clipped to it by a steel band which embraces it, being tightened by a suitable arrangement. As the carriers are fixed, they obviously must move with the rope and necessarily pass round the terminal wheels.

For this type the driving wheel is usually in the form of a special clip drum, and the terminal wheel, where the tightening takes place, is so arranged that the passing of the carriers can be easily effected. Where it is desired to unload, the carrier strikes a catch which causes the bucket to capsize or to open at the bottom, thus tipping or dumping its load.

Loading, which is a more delicate operation, can be effected by a variety of devices, all more or less ingenious and efficient. Thus a carrier can be loaded either while passing the driving drum, or at a point adjacent thereto, for instance by means of hoppers or cages moving at the same speed as the carrier and operated by it; or again, the ropeway may be run at the slow speed of 2 to 2½ miles per hour, in which case the carriers can be loaded or discharged by hand labour on passing the terminals. An interesting example of this kind of ropeway is mentioned by Mr Carrington as having been erected in Ceylon on a tea plantation. This has a length of about 3 miles, and passes over several steep ridges. The leaf (in bags) is placed in the carriers (which are in the form of cages) as they pass the driving terminal. This driving terminal is operated by wire rope transmission communicating the power required from a turbine ¾ mile away. The ground is much broken, necessitating the use of several guard wheels, which depress the rope; but as the load passes, its weight relieves the pressure on the

guard wheels, so that the load enables it to pass clear under the guard wheel, which latter again performs the office of depressing the rope immediately the load has passed. In this case the loads on arriving at the tightening and discharging terminal are lifted by hand off the carrier; but a simple automatic arrangement can be provided, by means of which a projecting bar is allowed to strike the carriers, whereupon the bags are delivered automatically.

The Double Ropeway.—In the double ropeway, which is the most generally employed type in these days, the load is carried on a stationary or rail rope, which serves much the same function as a railway track, except, of course, that the latter rests on sleepers, while the rope is carried through the air. This rope is fixed and taut, whilst the load is drawn by the second rope, which is called the hauler. The return is similar on a parallel fixed rope. This kind of ropeway is applicable in cases where the loads to be transported exceed 400 tons per day; where individual loads exceed 6 cwt.; where the incline exceeds 1 in 3, and where long spans are necessary.

The lock-coil rope (see Figs. 448, 449, and 450), which has been largely substituted for the old type of spiral rope, is here illustrated. It is undoubtedly possessed of great strength, has little or no tendency to twist, and has been installed under most satisfactory conditions involving heavy work and great strain on the ropeway.

Fig. 448.

Fig. 449.

Fig. 450.

Sections through Lock-Coil Ropes, as Manufactured by Latch & Batchelor.

A double ropeway is erected somewhat as follows:—

Two fixed ropes are stretched parallel to one another, about 7 ft. apart, and supported by trestles, fitted with saddles, at a distance of about 300 ft. from one another. These ropes are anchored at one of the terminals and tightened at the other by suitable gear. The carriers run on the fixed ropes as on rails, and are fitted with running heads carrying grooved steel wheels. The hanger from which the load is suspended is pivoted from the carrier, and the load is conveyed at a speed of 4 to 6 miles per hour by an endless hauling rope, operated by driving gear at one end, and controlled by tightening gear at the other. The hauling rope is coupled to the carrier by an automatic clip which holds sufficiently tightly to haul the carrier up inclines, but which releases itself by touching a bar on arriving at the terminal station. The grip of the hauling rope on the load may be supplemented by knots or sleeves on the former, or by means of suitable castings inside the rope and at certain distances apart in order to form an enlargement at the points where the clip engages. With slight inclines the pressure of two pulleys or plane surfaces on each side of the hauling rope is sufficient, but in the case of sharp inclines some more positive device is necessary. With lines erected on this system, the usual terminal gear as well as shunt rails are used, just as in the single rope lines. In addition to this, supporting rollers have to be provided at each of the trestles on which the hauling rope rests when it sags between the carriers. These rollers are provided with guide bars to increase the range of support, and guide the hauling rope into the above-named pulleys, should it be deflected from the vertical.

A line on this system, of about 1,800 yds. in length, is at work in Japan, running mostly at an incline of 1 in $1\frac{1}{2}$. It is used to carry ore from the upper terminal to the lower. Such is the power generated by the descending loads, that it has been found necessary to absorb the greater part of it, to render the line amenable to the control of a hand brake. With this view a hydraulic brake was introduced, in which the revolving fan drives the water against fixed vanes which again repel it. By this means about 50 H.P. was absorbed, and the speed regulated to a nicety by adjusting reaction vanes against which the water impinges.

A variation of this system is that of a *single fixed rope*, on which one carrier, hanging from the fixed rope, is drawn to and fro by an endless hauling rope. This kind of ropeway has been found useful under conditions where moderate quantities have to be transported in heavy individual loads, or where spans of considerable length have to be worked over. Inclines up to 1 in 1 can be worked, and spans up to 2,000 yds., while loads up to 5 tons may be carried. The endless hauling rope is operated by any available power, the driving gear being arranged with reversing motion so that the direction in which the carrier runs may be changed as required by the attendant. The fixed rope is supported on posts spaced at intervals varying with the nature of the ground, while the hauling rope is carried on pulleys fitted with guide bars and placed in the centre of the post over which the carrier passes, the posts, of course, being so arranged as to allow of the carrier clearing them. The return hauling rope may be supported on an outside pulley mounted on an arm of each post. The hauling rope is attached to the carrier head by suitably placing a pendant which causes it to pass under the saddle transom.

A ropeway, erected on this system by Messrs Bullivant, is at work on Table Mountain, at the Cape of Good Hope, and has a length of 5,280 ft. This line commences at the sea level, and following the ground on posts spaced about 300 ft. apart, takes a span of 1,500 ft., rising to a projecting rock 1,480 ft. above the starting point. Resting upon this support at this point, it again makes a span of 1,400 ft. to an upper terminal 2,170 ft. above the lower one.

Another type of ropeway is that which consists of two *fixed ropes* with an endless hauling rope manipulating one carrier in one direction, while the other runs on a parallel rope in the opposite direction. Such a ropeway can be used over long spans where individual loads amounting to 5 tons have to be transported. It would be suitable in cases where the ropeway could be worked by gravity, the descending load moving by its own weight, while the empty carrier ascends. In such cases spans of 2,000 yds. or more may be safely negotiated, and loads of 6 tons carried.

Gripping and Other Coupling Devices,¹ by means of which the carrier is attached to the hauling rope, are some of the most important details of a double ropeway, and must fulfil the following conditions:—

Firstly, the attachments must have such a grip on the rope that the carrier can ascend inclines of 45° in safety without tendency to slipping.

Secondly, the hold or grip on the rope must be entirely by friction, as any bending of the hauling rope by the coupling will inevitably shorten the life of the rope.

Thirdly, the apparatus should be so arranged that the amount of grip is adjustable according to the circumstances, taking the wear of the rope and climatic and atmospheric influences into account; and

¹ The Author is indebted to A. Pietrkowski for some of the information which appeared in an article in *Stahl und Eisen*, 18th November 1908.

Lastly, the operation of coupling and uncoupling should be performed automatically at predetermined points.

Under the second heading it should be mentioned that sufficient compression of the rope to obtain the necessary grip is in itself by no means advantageous to the rope, so that a tendency to bending it would aggravate the evil very considerably.

Under heading three is included the consideration of sufficient latitude in the ability of adjustment to allow for the variation in thickness which is often noticed after the rope has been at work for some time; this also includes splices, and the slippery condition of the rope from wet and hoar frost.

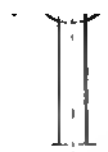


Fig. 451. Obach Coupling.

Appliances which satisfy these conditions are in use at the present day, and we will now pursue their development in chronological order.

The coupling illustrated in Fig. 451 was designed by Obach. It dates from 1870 and was probably the first device of this kind ever made. It was an application of the principle of the eccentric, and was exceedingly simple. The rope rested on roller *b*, and the eccentric *a* turned until it gripped the rope which travelled in the direction of the arrow (see drawing), and thereby helped to tighten the eccentric against the rope; but as the grip on the carrier depended solely on the friction between rope and eccentric, it was not very great. The method of coupling or uncoupling was exceedingly simple, being effected by either dropping or lifting lever *c*. The weak points of this early appliance were that in the event of a temporary slackening of the speed of the rope, the carrier, by reason of its momentum, would proceed faster than the rope and would thereby tend to loosen the coupling, so that if any of the carriers were on an inclined portion of the rope they might run back.

To remedy this defect was the first move towards an improvement, and the outcome was a new appliance brought out in 1874 by Bleichert & Otto; this is shown in Fig. 452. The essential feature of this appliance was a reversal of the action of that described previously, that is to say, the eccentric *a*, or rather an eccentric segment, had its smallest radius towards the rope instead of vice versa, so that in whichever direction the rope or the load might pull, it had a tendency to grip and hold fast. As, however, this arrangement by itself did not give sufficient latitude, the turning point *b* of the eccentric has been made movable at one end of the bracket *c*, so that by the movement of the angle bracket *c* the relative position of the eccentric to the rope could be changed within larger limits.

The grip of this improved coupling was, however, not sufficient for heavy duty, as it

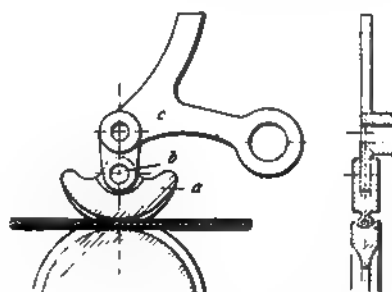


Fig. 452. Bleichert-Otto Coupling.

also depended solely on the friction between rope and eccentric. The appliances, Figs. 453 and 454, marked a further improvement by the same firm. It consisted of a roller *a*, and a segment of an eccentric *b*, which was movable around a pin *c*; this pin coupled the eccentric to an extension *d*, which was guided in a cast-iron bracket where it could move up and down; this extension *d* was manipulated by a second eccentric *e*. To the axle of this second eccentric was fixed a lever *f*, provided with a handle, and it will be seen that by the movement of this handle the eccentric *b* was pushed down upon the rope in the position shown in the drawing. The rope was gripped by the eccentric *b*, but the eccentric motion, or grip of eccentric *e*, had not yet come into force, and this would give an auxiliary grip when the rope pulled in either direction. This apparatus was quite satisfactory for ropeways which negotiated moderate inclines and for moderate loads. More modern installations, with inclines exceeding 1 in 3 and heavier loads, require a coupling of still greater gripping power. Experts realised the difficulty of such a design, and therefore adopted the expedient of a rope with knots as an easy way out of the difficulty. These knots were attached in a variety of ways to the rope at fixed intervals, each knot

Figs. 453 and 454.

Bleichert Couplings.

Figs. 455 and 456.

engaging with the coupling of one of the carriers, and this had the advantage of distributing the load uniformly over the rope, but it had the drawback over the previous promiscuous method of attaching the loads, in that the capacity of the ropeway could not so easily be altered. It is not here intended to describe at length the various methods of attaching the knots to the rope; they were either securely attached to the strands of the rope and thereby made a fixture, which, as we shall see later, was not found a good plan, or they were made movable so that they could be taken off and fixed in a fresh position. The latter also had the advantage of being attached quickly and easily, but they lacked security in their position and were apt to shift. A rope thus fitted with knots would not require a gripping device, but rather what is known as a locking grip or coupling, so it was necessary to reconstruct the coupling to accommodate it to these altered conditions. The illustration, Figs. 455 and 456, shows a design of Adolf Bleichert's, which consisted of a rope roller *a* and bracket *b*, which carried the sliding block *c*, and this carried two bolts or pins *d* and *e*, which latter had at their base peculiarly shaped fangs or claws. The bolt *d* admitted of a vertical movement and was held in its normal position by a spiral spring. The method of coupling the carrier to the rope was performed as follows:

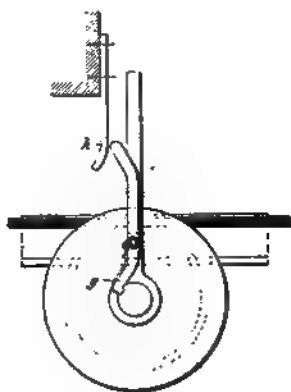
As soon as one of these knots approached the coupling it lifted the fangs of the bolt *d* and slid underneath, its progress being arrested by the fangs of bolt *e*. The spiral spring replaced the fangs of bolt *d*, so that the coupling and carrier travelled with the rope. The hook *f* was connected with the pawl *g*, for the purpose of uncoupling the carrier.

Another construction for the same conditions is that of Elligen, shown in Figs. 457 to 459. This consisted of the frame *b*, roller *c*, and catches *d*, which latter were the chief features of the coupling. They were arranged on either side of the roller *c*. In the illustration they are shown in the lowest position, as they rest upon each other at *e*; the rods *f* engage with

Figs. 457 to 459. Elligen Coupling.

a short length of rail at the stations, thereby lifting the catches, thus uncoupling the rope, as shown in the lower picture. The uncoupling process being similar to that of the previously described appliance, owing to the insecurity of some of the knots on the rope, and the great wear on both sides of the knots caused by these couplings, it was realised that their employment did not solve the difficulty in the best and most economical way, and further efforts were made to design such a coupling as would give sufficient grip for steep inclines and heavy loads without the use of knotted ropes.

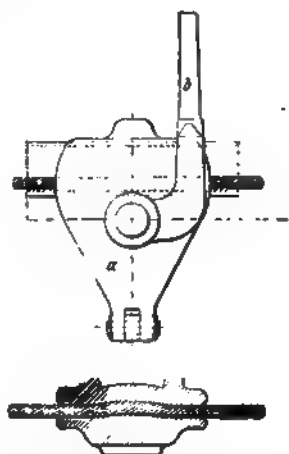
Theodore Otto abandoned the eccentric principle for these couplings in 1877, and introduced a gripping device on the screw-vice principle. It would occupy too much space here to explain why this screw device was not introduced before, but the chief difficulty was that a certain clearance between the gripping device and



Figs. 460 and 461. Otto Coupling.

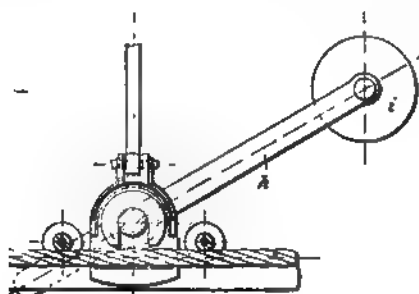
the rope was always necessary; and to close the jaws when sufficiently far apart until a sufficient grip was obtained, the coupling lever would have to traverse a larger segment of a circle for a screw device than for an eccentric device (the latter takes less than 90°), and if so short a movement of the tightening lever is chosen for a screw device, the pitch of the screw has to be so steep that there is a danger of its coming undone through

a little vibration, unless an automatic catch is provided to prevent this, and that is the plan adopted by Otto. His device is shown in Figs. 460 and 461; *a* shows the portion of the carrier to which the apparatus was attached, which consisted of the disc *b* with pin *c*, upon which latter was a second disc which could revolve on the same, and which was controlled by the thread *d*. When the handle *e* was turned, the loose disc was pressed against the fixed one and thus held the rope *f* as in a vice, the catch *g* snapping into position and keeping the grip tight. The coupling operation was performed by hand, whilst the uncoupling was effected automatically by tripper *h*. If the clearance mentioned above was somewhat reduced, so that a lesser movement of the lever was sufficient for the grip, the catch could be dispensed with, as the thread of the gripping screw was shallower. Figs. 462 to 464 show such a coupling; the arrangement is similar to the foregoing, but more like a vice. In order to intensify the power, the gripping portion has a slight bend in it (see illustration). This coupling is used by hand only, and even this slight tendency to bend the rope is not advisable, from the economic point of view.



Figs. 462 to 464. Improved Otto Coupling.

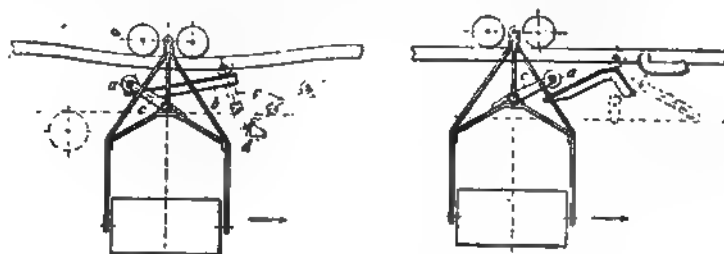
At the same time Obach experimented, independently of Otto, with a coupling on the vice principle, but realised that the rope must be gripped in its central position in order to get the tightest hold, and at the same time cause the least possible injury. This prompted him to abandon the single screw, and substitute for it a gripping



Figs. 465 and 466. Werner Coupling.

device actuated by a right and left handed thread, which had the advantage that the gripping surfaces moved towards each other, and that, without making the thread of the screw too steep, the arc described by the coupling lever was not more than 180°. This principle was further developed by Alexander Werner in 1885, who improved on the idea by using different threads on the two halves of the grip, the one with a fast pitch, whilst the other was provided with a thread, so that each half of the coupling had to perform a different kind of movement, and altogether they exercised a very powerful grip on the rope. One such device is shown in Figs. 465 and 466

in front view and section. The component parts were a spindle *a* which carried a right-hand thread of a steep pitch marked *b*, and a portion *c* with a fine left-hand thread. Both portions of the screw fitted into and carried each half of the gripping portion *l* and *k*. The spindle *a* was secured to the carrier frame *n*; lever *h* was keyed to the spindle and carried a balance weight *i*. If this lever *h* was moved to the left the jaws opened, whilst, if it was turned to the right, it closed in such a way that first the jaw *k*



Figs. 467 and 468. Application of Werner Coupling.

with the quick thread closed upon the rope, and with any further movement of the lever the slow pitch screw closed the other jaw. The whole of this could be performed by a movement of not more than 90° of the coupling lever. Figs. 467 and 468 show the automatic opening and closing of the grip. To couple up, the workman pushed the carriage in the direction of the arrow when the coupling lever *a* engaged with an inclined plane *b*; this lifted the lever into an upright position when the lower end *c* of the lever engaged with the tripper *d*, which forced the coupling lever right over through an arc of 90° from its initial position, and secured the clamp to the rope. The uncoupling, which is shown in the same illustration, is a reversal of the action, as may be seen in the various positions in dotted lines.

In the year 1887, Mr J. Pearce Roe devised and employed a clip for a ropeway under his own supervision, where the grip was obtained by two wedges placed normally on a horizontal plane, which gave excellent results on gradients of 1:2. In this clip the amount of gripping was in direct proportion to the steepness of the grade, and, therefore, exactly what was wanted. Unfortunately the device was too costly to be generally adopted.

Figs. 469 and 470. Bleichert's "Automat" Coupling.

In 1894, about the same time that the Werner Coupling, which went under the name of "Universal Clip," was at the zenith of its popularity, a different principle altogether was introduced by Paul Spitzek, to whom it occurred that the weight of the carriage itself might be utilised for coupling it to the hauling rope. Attractive as this idea appeared at first sight, the bringing into practice presented many difficulties, all due to one main cause, *i.e.*, the fact that one half of the gripping device would have to be attached to the trolley on the rail rope, and the other portion to the carrying frame suspended from it, and which might be at right angles to it when the rope was horizontal; or form a sharp or obtuse angle when the carriage negotiated upward or downward

inclines. The problem was, however, solved in 1896 by the introduction of a device by Bleichert, illustrated in Figs. 469 and 470. This grip goes by the name of the "Automat," and consists of a sliding block *a*, which moves in a vertical direction in the frame *b*. A pin *c* is attached to this block, and the carrying frame *d* is suspended from this pin. One of the jaws *e* is rigidly connected with the framework of the trolley, whilst the other one *f* is connected to the sliding block *a* (and indirectly to the pin *c*) by a connecting link *g*. The throwing in and out of this coupling is effected by slightly raising or lowering the load on the rope. The roller *h* is for this purpose, as this rests on small auxiliary rails at the loading or unloading stations. It is claimed for this coupling that the grip is sufficient to fulfil all the requirements of the modern ropeway without the use of knotted ropes.

Advantages and Disadvantages of the Two Rope Systems, of which, as regards the initial outlay, the single ropeway is simpler, having only one rope and requiring no expensive couplings; it is therefore less costly, although the supports should be closer together, as it is more difficult to keep a running rope taut than a stationary one. The working expenses, that is the labour, would be the same in both systems.

The double ropeway is more applicable to difficult routes deviating from the straight line. It can negotiate steeper gradients and, finally, it is more suitable for large individual loads than the single rope system; firstly, because corners are more easily turned with a double ropeway; secondly, because the Λ -shaped saddles do not exercise so positive a grip as do some of the gripping devices of the double ropeway; and thirdly, because the rail rope is stronger, tighter, and thus more rigid, to cope with heavy individual loads.

A rope of the single system can be minutely examined and oiled whilst passing through one of the terminal stations, but with a double ropeway a man has to travel in one of the skips for this purpose.

Cost of Transport.—This must necessarily vary with the conditions, but, generally speaking, the working expenses of a ropeway compare favourably with those of a railway. On some well-planned and well-laid ropeways the wear and tear of the ropes, which is actually the largest item of expense, is said to be between $\frac{1}{8}$ d. and $\frac{1}{4}$ d. per ton per mile. Broadly speaking, the cost of handling must vary with the natural obstacles on the route and the quantities to be carried.

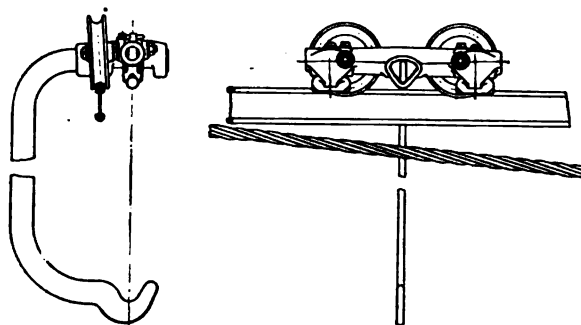
An example chosen to show the wear and tear of rail ropes is a ropeway erected by Messrs Bullivant & Co. Ltd., in Spain, which was employed to convey loads of from 300 to 350 tons per day a distance of 1 mile between Badovalle and Ortuella, so that it is estimated that one rope carried over 160,000 tons. As the ropeway was at work incessantly from July 1893 to July 1895, the cost of rope renewal meant an expenditure of $\frac{1}{4}$ d. per ton per mile. The rope when new had a breaking strain of $29\frac{1}{10}$ tons, and the test showed that the disused rope had still a breaking strain of $27\frac{1}{2}$ tons.

As will be seen later, Ropeways Ltd. estimate the total cost, including, in addition to rope wear, all renewals, grease, stores, etc., at $\frac{1}{2}$ d. per ton per mile. The figures given do not, however, include cost of labour or power, which two items vary with every installation.

Cost of Maintenance.—One of the most important questions in a ropeway installation is the cost of maintenance, and as this is almost exclusively confined to the renewal of the rope or ropes, it may be well to investigate this subject more fully. It is obvious that the function of and the demand upon a rail rope is different to that of a haulage rope. The former would naturally have to be made of the stoutest possible wires

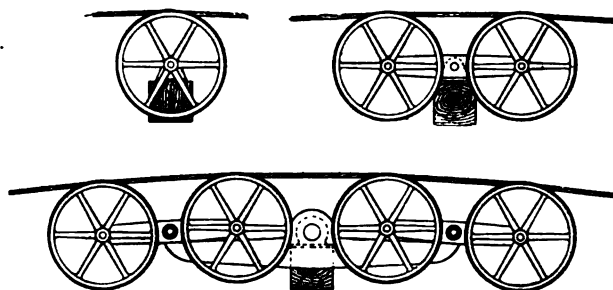
to form a rigid, smooth, and lasting rail for the load to run upon, whilst the latter, which would not be exposed to much actual external wear, but mainly to that due to tension and bending, should be composed of thin wires of good quality steel, in order to give flexibility and strength.

Now with a single ropeway both demands of tensile strength and rigidity are made upon one and the same rope, and it is therefore apparent that such a rope must be chosen as will meet both these demands. It is difficult to arrive at a happy medium in order to meet such conditions, and the single ropeway is under a disadvantage. The single



Figs. 471 and 472. Single Rope Carrier employed by Ropeways Ltd.

rope, though always running, is working under similar conditions to the fixed rail rope of the double ropeway; only instead of the rope with its load running over stationary rollers as in the first case, the running rollers with their load pass over the stationary rope in the second case. The stationary or rail rope of the double ropeway may be subjected to greater local strain, and consequently wear more at certain points of its length, and being a fixture may wear principally on the uppermost side, whilst the single rope, which



Figs. 473 to 475. Grouped Sheave Mountings with Balance Beams.

constantly travels the whole route, must of necessity wear equally on the whole of its length, as every portion must negotiate any point causing extra wear, and as it always revolves slowly round its own axis, it is worn equally all round. The rail rope of the double ropeway can of course be relaid from time to time, whereby this defect may be minimised.

If we summarise the foregoing we find that the two ropes of the double ropeway can be better adapted to their diverse requirements than the single rope, which has to combine both requirements. On the other hand, the rail rope of the double

ropeway is, under certain circumstances, subjected to greater and always to more or less unequal wear.

It appears, therefore—and this is borne out by practical results—that there is not much to choose as to the expense of rope renewals, provided that both types are designed equally skilfully, and that no excessive loads or spans are attempted.

Installations by Ropeways Ltd.

The attention of Ropeways Ltd., of which Mr J. Pearce Roe is managing director, has been chiefly confined to the design and construction of installations on the single

Fig. 476. Quadruple Balanced Beam and Sheaves.

or mono-cable system, and the double or bi-cable type is only used by them where short lines of heavy capacity are required. By careful attention to details, this firm have mono-cables running which are carrying 150 tons per hour, working grades exceeding 1 in 2½ over rough and mountainous country.

The saddle which enables them to negotiate such steep gradients is shown in Figs. 471

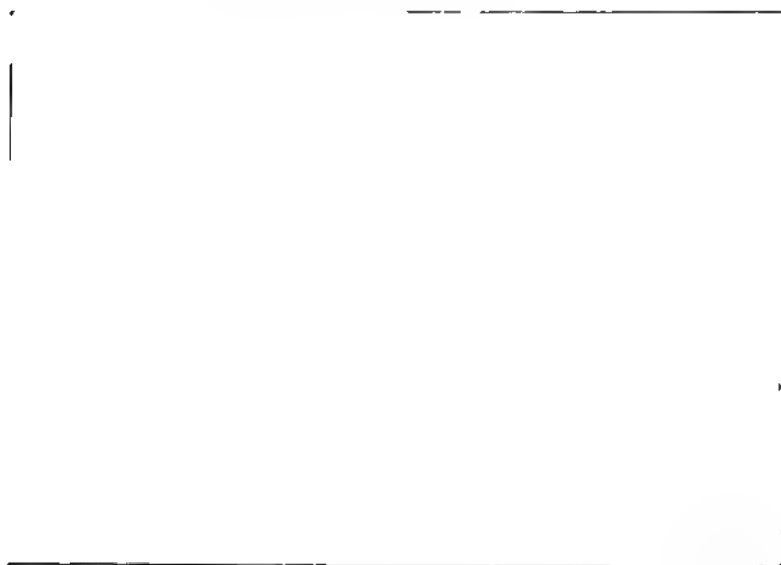
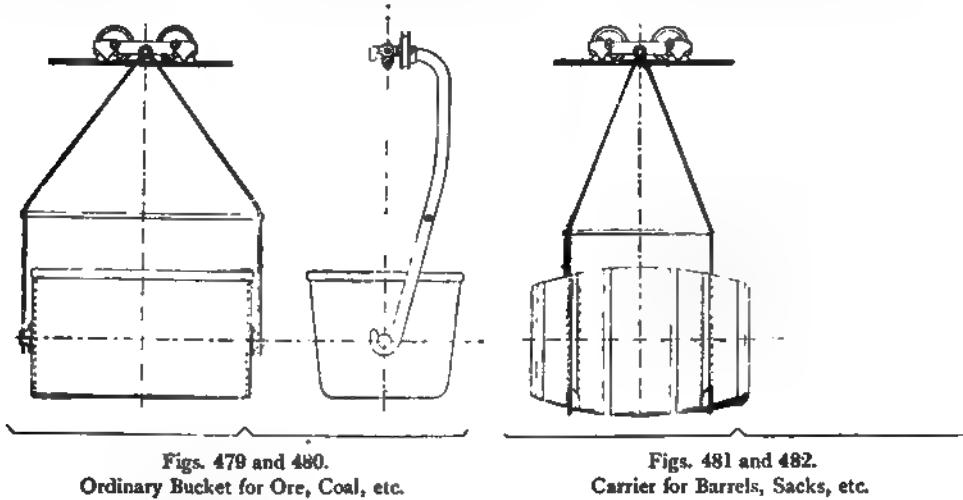


Fig. 477. Multiple Balanced Beam and Sheaves.

Fig. 478. Portion of Ropeway of the Compañia Minera Minas del Riff at Melilla.

and 472. The two surfaces which come in contact with the rope have two wart-like projections, each of which fasten between the coils of the rope, and prevent any slip.

Ropeways Ltd. have recently introduced a new carrier-head which will permit of gradients of $1:1\frac{1}{2}$ being worked. It consists of a mechanically operated pinch-clip for negotiating gradients steeper than $1:2\frac{1}{2}$. The movement of the jaws is obtained



through a combination of "scissors" type of grip acting against cams. The contact surfaces are so arranged that a very wide opening to the clip jaw is obtained with comparatively little downward movement of the same; but, on the other hand, a very heavy pinch is produced when the clip is in its upward position, or, in other words, on the rope. The device is actuated by the carrier and load.

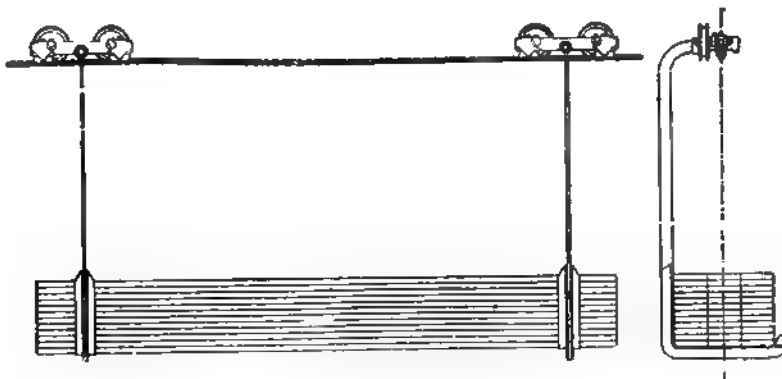
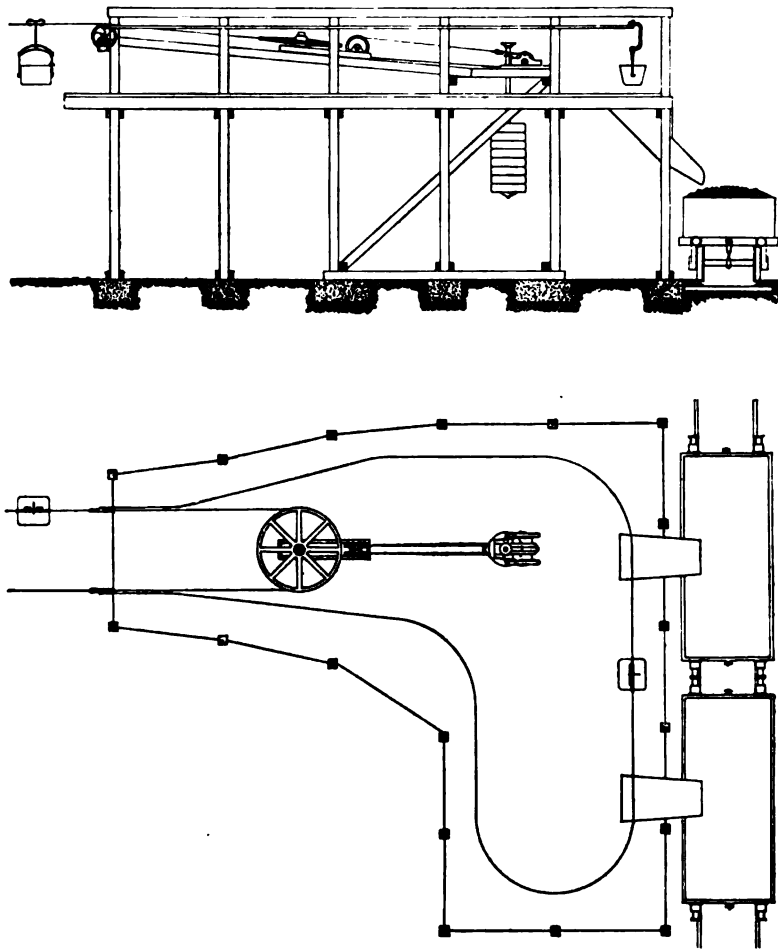


Fig. 493. Carrier for Timber.

Another feature of this system is the grouping of balanced sheaves to support the rope. Illustrations of their single, pair, and multiple balanced beams and sheaves are shown in Figs. 472 to 477.

Grouping sheaves in this manner simplifies the construction of ropeways, and enables long spans to be worked without undue pressure on the supporting sheaves, as the balanced beams allow the sheaves to adjust themselves and follow the angle due

to the direction of the passing rope, so that the pressure is equally divided all the time on every sheave with no detrimental effect on the rope. The ropeway of the Tominil Mexican Mining Co. may be cited as an example of this kind. Its length is 2,400 m., and it runs over a series of rugged ridges, and only eight trestles of 3 m. each in height are employed for supporting the rope, the longest span being 810 m.



Figs. 484 and 485. Plan and Elevation of Tension and Discharging Station.

A very similar line on the same system has recently been constructed in Bolivia, where one of the spans measures over 1,000 m. between supports.

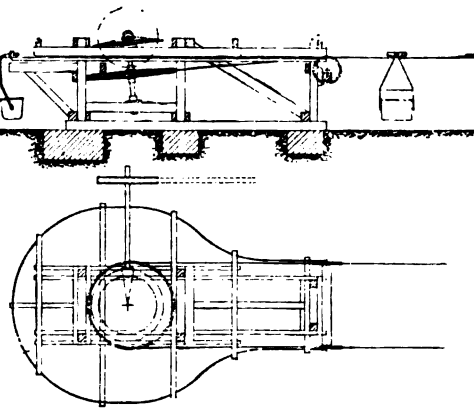
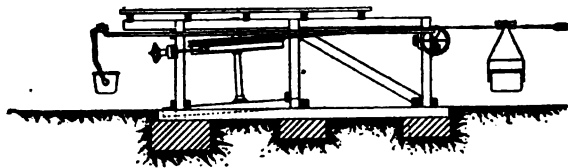
The greatest length worked in one continuous section on the system in question is the lower half of a ropeway built for La Compañía Esplotadora de Salinas, in Chile, which is 8,500 m. long between stations, or, in other words, requires an endless rope of 17,000 m. The heaviest line is that installed for the Compañía Minera Minas del Riff, at Melilla, which nominally carries 150 tons per hour, but which has actually carried 170 tons per hour. In Fig. 478 a portion of this line is represented.

A series of lines having a total length of 23 km., built in 1903 for the Bacares Iron Ore Co., give a good example of the low rope wear on this system. The ropes of two units of this installation have, in each case, transported over a million tons of ore. Among other instances of long lives of ropes a line may be mentioned, built for the Cork-Bandon South Coast Railway; here the same rope has been running for twelve and a half years; and on an installation constructed for Messrs Newell at Dalbeattie, the original rope has been working for twelve years.

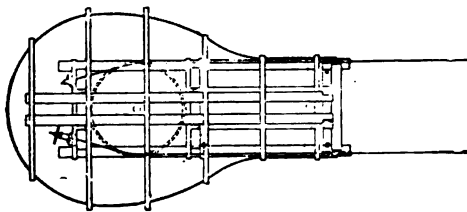
A few forms of carriers used for different purposes are illustrated in Figs. 479, 480, 481, 482, 483, while Figs. 484 and 485 show plan and elevation of unloading and tension station built on the single rope system by the above-named firm.

Other examples of Roe's unloading stations are given in Figs. 486 to 489, the former two representing terminals for driving by power, whilst the latter two represent loading terminals for a gravity driven line, showing band brake. These brake stations of gravity lines are also fitted with hydraulic resistance regulators in order to automatically govern the speed of the ropeway.

An angle station is represented in Fig. 490. This is at a point where the ropeway diverges slightly from a straight line. It is in use on the Mazapil Copper Co.'s ropeway in Mexico, and has a capacity of 250 tons per day of ten hours.



Figs. 486 and 487.
Plan and Elevation of Driving Terminal.



Figs. 488 and 489. Plan and Elevation of Brake Terminal.

A new device for passing buckets automatically through angle stations and round return terminals has recently been brought out by the firm of Ropeways Ltd. Instead of the ordinary fixed shunt rail being used, a specially constructed creeper chain is employed in its place, the speed of movement of which can be varied, but normally runs about half the speed of the rope. The chain is supported by a series of bottom and side rollers contained in a trough. When the carrier leaves the main rope and takes on to the chain it will,

of course, come to rest and travel along at the same speed as the chain. At the take-on point the chain is graded sufficiently to allow the carrier to start by gravity accelerating, so that when the clips engage with the main rope, the carrier will be moving at the same speed as the rope. The chain is composed of a series of castings which are bolted round a flexible rope. With this arrangement any reverse curves can be taken.

When analysing the costs of stores and general renewals on various installations, these figure out roughly at $\frac{1}{2}$ d. per mile per ton of material carried on average lines

Fig. 490. Angle Station on the Ropeway of the Mazapil Copper Co.

of about 40 tons capacity, and vary with the load or capacities above or below. This cost includes rope wear, all renewals, grease, stores, etc. It is, of course, impossible to give ton-mile rates for labour and power, but it can be taken that five men are capable of working a straightforward installation of a capacity up to 60 tons per hour, and a

length of 4 miles, if the material carried can be handled cheaply from bunkers and shoots, yet without introducing any special automatic appliances. On some lines no more than three men are employed.

Messrs Ropeways Ltd. have just completed what is believed to be the longest ropeway in the world, for the Dorada Railway Extension Co. of South America, between the two towns of Mariquita and Manizales in the Republic of Colombia, South America. This line has a length of 45 miles (73 km.) measuring the distance horizontally, but as the ground over which the line runs is exceedingly mountainous, the actual length over the trestles greatly exceeds this. The line is divided into fourteen stations, and the power

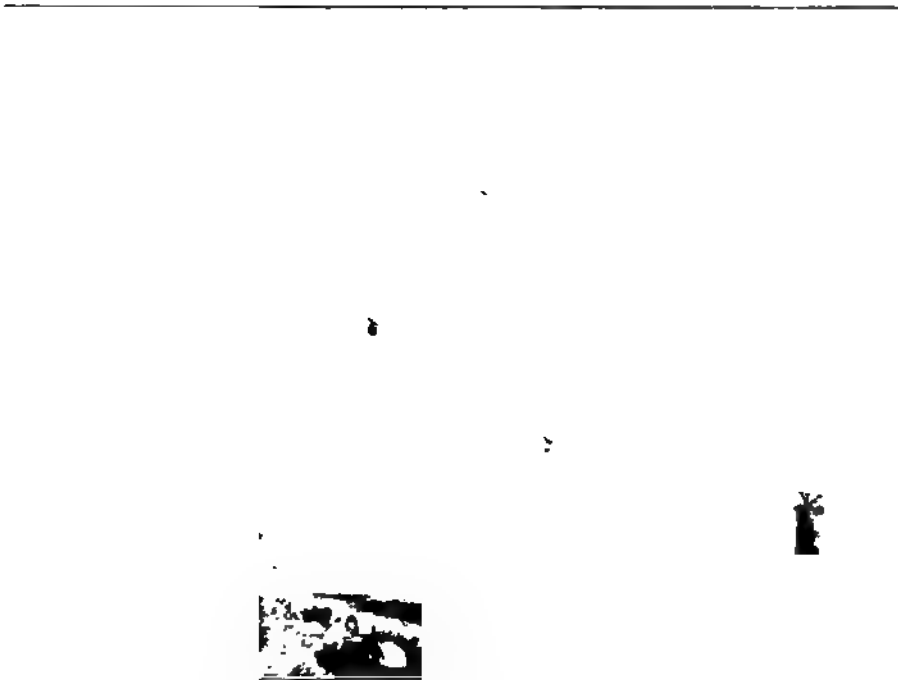


Fig. 491. General View of the Ropeway.

required for driving it is about 400 B.H.P., produced by a hydro-electric plant erected on one of the local rivers. The installation conveys general merchandise, and has a maximum capacity of 20 tons per hour in both directions at the same time throughout the whole length.

Ropeways Erected by Bullivant & Co. Ltd.

Ropeway in Connection with the Beachy Head Lighthouse.—The ropeway employed in the erection of the well-known Beachy Head Lighthouse in 1900 not only affords an excellent example of the ways and purposes in and for which ropeways can be employed, but it is also of historic interest. Having served its transitory purpose, it has now disappeared, but the heavy chains and rings on top of the cliffs adjacent to the lighthouse, to which the ropeway was anchored, are still in existence.

It was desirable to establish the workyard at the top of the cliff at a height of about

400 ft. above the sea. It became necessary to construct a ropeway of a special character for the purpose of carrying loads to a staging erected a little beyond low-water line on the shore at the site of the proposed lighthouse, which lay about 600 ft. from the base of the cliff (see Fig. 491).

The late Mr W. T. H. Carrington, M.I.C.E., consulting engineer to Messrs Bullivant & Co. Ltd., having in consultation with Mr Matthews prepared the necessary designs for the ropeway, the construction of the latter was entrusted to that firm. The chief work the ropeway was required to perform was to transport blocks of granite weighing about 4 tons each for the construction of the lighthouse. It had also to transport the machinery needed in the building, such as pumps, steam engines, cranes, etc., as well as all the cement, shingle, etc. In addition to this it was also necessary that the ropeway should provide a convenient means for the conveyance of the workmen down to and up from their work on the lighthouse (see Fig. 492).

As in ordinary working the descending load draws the ascending load up, a modification was necessary in order to provide for bringing up workmen when no materials were ready to send down. A small auxiliary steam engine was therefore provided.

The arrangement of the plant was as follows: Two fixed ropes—one 6 in. in circumference with 120 tons breaking strain, and the other 5½ in. in circumference with 100 tons breaking strain—were stretched parallel to each other between the termini. These ropes terminated at the upper end at a massive wooden trestle carrying tension bars fitted with thimbles suitably supported in brackets on its summit, to the outer thimbles of which the above-named fixed ropes were attached, the strain being transmitted through the tension bars to tie-backs attached in the rear, transmitting the strain to the anchorage further in the rear. Thus the fixed ropes, at the point where the strain was most severe, were not subjected to any bending action.

Fig. 492. Men Returning from Work.

At the lower terminal it was necessary to transmit their strain to an anchorage in the rear of the staging, since the staging itself was not constructed to safely take any side strain. The lower ends of the fixed ropes were therefore attached to double screw tightening gears, which in their turn formed the end of the back tie-bars. These were made of steel, connected by pins, terminating in anchor bars buried in the chalk at the bottom of the sea some distance in the rear of the staging, concrete being filled up round them and placed over them in such a quantity as to resist the pull.

The tightening was accomplished by an arrangement of two screws, combined so that when the tightening was effected by one screw, the other acted as a fulcrum, and reduced by one half the strain necessary to apply on the screw for tightening. This tightening gear, with a drift of about 8 ft., was carried on a strong wooden frame placed on the staging above referred to, and advantage was also taken of this frame to carry suitable ead-on pulleys and a wheel, round which the return hauling rope passed.

The stones—the heaviest loads—always descended on the 6-in. rope, while on the parallel rope a balance load was run, which the stones descending drew up, thus considerably reducing the necessary brake power. This system of working was necessary only in the transport of the stones and very heavy loads. The ropes were used indiscriminately for the transport of lighter loads. It is estimated that the working strain on the 6-in. rope was about 30 to 34 tons, and that on the lighter rope 25 to 27 tons.

On each fixed rope was placed one carrier. That for supporting stone was fitted with an

Fig. 493. Last Stone.

eye, to which the Lewis bolts in the stone were shackled; that for the balance load held a receptacle which could contain about 2 tons of either ballast or chalk, which could be tipped, when it afforded accommodation for about twelve workmen.

An alternative receptacle could be attached to the carrier for the handling of stone on the 6-in. rope when the carriage of workmen or of ballast, cement, etc., was required.

Attached to the two carriers was a running head, with four steel running wheels, which fitted the rail ropes. These wheels were articulated in pairs, to equalise pressure on the rope. One end of the hauling rope was attached to the upper end of the running head, and passed on the upper terminal over a pair of 6-ft. guide pulleys and thence to a brake gear in the rear. The other end of the haulage rope was attached to the lower

portion of the running head, led down to the lower terminal, where it passed over two 4-ft. guide pulleys, thence round an 8-ft. return wheel, fixed, as already stated, to the tightening frame.

The brake gear consisted of two 8-ft. diameter wooden grooved wheels, each fitted with a brake sheave, the whole carried on a vertical shaft. These brake straps were supported on one standard, and brought together at the other standard by means of levers working in opposite directions operated by screws. A suitable suspension

Fig. 494. Last Stone being put in Position.

arrangement was provided to keep the brake straps free from the flanges of the brake ring. Subsequently, owing to the necessity of applying steam power for bringing up workmen, etc., a bevel rim was fitted to the lower brake wheel, which, working in conjunction with a bevel pinion carried on a shaft, in connection with a steam engine, was employed when it was necessary to work the line by steam.

As it was necessary that the man who worked the brakes should have a full view of the movement of the carriers, chain wheels were fitted to the screws which operated the brakes; these communicated by chains with two other chain wheels with hand wheels fitted to the trestle frame which stood at the edge of the cliff.

The hand wheels were placed close to one another, so that when the brakesman was operating the ropeway with one brake, he had another immediately in reserve should anything fail. As a matter of fact, one brake strap controlled the load; the other, therefore, served as a spare one.

For the loading of heavy weights, a lift, worked by hand, was provided in the loading position of the carrier on the 6-in. rope, which, as stated above, was the only one employed for the carriage of stone. The lift, which was fitted with a moving platform provided with rails, was supported by locking gear in a position to bring the stone from the depot on the rails of a tramway. This having been done, the load was raised by operating a twin-grab winch, which simultaneously moved four ropes attached to the four corners of the platform. As soon as the stone had been raised sufficiently it was shackled to the running head, and the platform with the truck allowed to descend slowly into a pit, which was sufficiently deep to allow the stone, suspended from the carrier, to pass over the platform and empty truck. As this platform and truck descended slowly, the strain was allowed to come gradually on the carrier, and therefore on the ropeway. After the carrier had departed with its load hanging from it, the platform of the lift was raised, with the empty truck on it, and arriving in locking position, the truck was run off. This operation was repeated every time a stone was sent down.

Figs. 493 and 494 show the conveying and putting in place of the last stone.

The erection at Beachy Head was carried out by the contractors under the supervision of Mr Havelock Case, M.I.C.E., resident engineer for the Beachy Head Lighthouse Works.

Ropeway in the Anaimalai Hills.—The Anaimalais (elephant mountains) of Southern India are an important centre of timber supply. The forests in this region, though much overworked in the past, still contain a large supply of exploitable wood of valuable kinds, chiefly teak, which is handled by a wire ropeway. The climate being unhealthy, this range of hills is almost uninhabited by man, but is infested with wild animals.

Under the system formerly employed in working these forests, the huge logs were dragged by elephants to the side of a 2-ft. tramway, and transported on trolleys to the end of the line, whence they were sent down the ghaut road by bullock carts into the nearest town, about 50 miles distant.

These methods have been reformed by the establishment of a saw-mill in the forest driven by a Pelton water wheel, where the timber is sawn into marketable sizes. By the erection of a wire ropeway overlooking the plains, the use of the ghaut road—the most costly section of the journey—is dispensed with. The wire ropeway takes off from the lower end of the tramway line, while its lower terminus is close to the main road. The wood is conveyed from the saw-mill by the tramway direct to the wire ropeway, and in this way reaches the foot of the mountain.

The ropeway was erected by Bullivant & Co. for the Forest Department of the Madras Government. A loaded carriage travels down a main fixed rope by gravitation, hauling up an empty carriage on the same rope. The two carriages meet in the centre, and are there transferred by an arrangement described below. The descending carriage is controlled by an endless hauling rope adjusted below the main rope, passing twice round a brake drum, and kept in check by a powerful brake strap, and a large deeply-grooved wheel at the foot.

The hauling rope is clipped on to the two carriages on the right-hand side, looking in the direction in which each is travelling.

The ropeway between the terminals is 6,318 ft. long, and the length of line actually traversed by the carriages 5,284 ft.

It became necessary to advance the starting platform sufficiently to bring the central or transfer platform on to a ridge within easy distance of the rope. The total fall from

terminal to terminal is 1031.58 ft.; that from the upper terminal to the starting platform, 109.50 ft.; from the starting platform to transfer staging, 488.70 ft.; from the transfer staging to the lower terminal, 433.38 ft. The rope crosses two main valleys and a number of ravines, the ground being much broken up and rocky in parts.

There are six main spans of 554, 1,675, 510, 600, 355, and 712 ft. respectively. The rail rope is $2\frac{7}{8}$ in. in circumference, while the diameter of the hauling rope is $\frac{7}{8}$ in. The brake drum is 4 ft. inside diameter.

The brake strap is adjusted to the upper half of the drum and acted on by a lever at the side. The lower part of the drum is cased with hard wood and hollowed out to prevent the folds of the rope overlapping. The axle of the drum runs easily in deep substantial bearings. The large grooved wheel at the foot is 4 ft. in diameter.

The hanging supports consist of two curved wrought-iron plates 3 ft. long, forming a circular opening at the top 8 in. in diameter, and connected at the lower end by a grooved saddle in which the rope rests, sloped at the ends to prevent injury to the rope.

The saddles are of cast iron, of similar construction, and are used in a few places, resting upon wooden brackets and supports projecting from them conveniently near the line.

The carriage consists of two curved wrought-iron hangers, connected together by pieces of timber with grooved runners, 9 in. in diameter, with $1\frac{1}{2}$ -in. grooves. Two-wheeled carriages were first used, but experience has shown that it is best to use such with four wheels. Four clips are attached to each carriage. Each clip is provided with a clamping screw, while the hauling rope is attached to the right-hand side of the descending carriage.

The nearer the wheels are brought together the more easily the carriages will travel. When the wheels are placed some distance apart, they do not travel on the same plane, and set up much friction on the rope.

The first step towards the installation of the wire ropeway was the selection of the most convenient line, and clearing it—a by no means easy matter, as it lay through thick forest. The supports were then set up.

The unreeling of the rope followed, commencing, of course, from the bottom of the line. This was sent out on a large iron reel or bobbin, the total weight of the rope and reel being about 4 tons. An axle was passed through a hole in the centre, and the reel was swung clear of the ground.

It was at first intended to unwind the rope and carry it uphill on the shoulders of coolies, placed at intervals of 30 ft., but the broken nature of the ground made this difficult, and eventually elephants were attached to the end of the rope to haul it up. The friction caused by the rope dragging along the ground was, however, so great, that at the end of the journey no less than nine elephants were at work in addition to a large body of coolies.

Spliced into the end of the rope was a massive thimble, or eyelet. This was attached to the chain, and the rope was fixed to its upper anchorage. It was then raised on to the supports, connected to the anchorage cable at the lower end, and hauled in by means of a winch, provided with the necessary two and three sheave blocks. Sufficient tension was obtained to give a dip in each span of about one in forty.

The unreeling of the hauling rope followed, and the two ends were joined. This rope is, of course, adjusted below the fixed rope, and drawn reasonably tight. The up-and-down sides are arranged 18 in. apart, corresponding with the distance between the inner edges of the clips on the carriage, and kept in that position by means of fixed guide wheels, which lead the rope to the drum and large wheel at the foot. It was a matter of some difficulty to overcome the friction set up in this rope, which checked the loads. The design of rollers had to be changed several times, the last and most successful

being large grooved pulleys, about 18 in. in diameter, running easily on their bearings, and provided with wooden guides placed above them to lead the haulage rope into the grooves.

The supports for the hangers and saddles vary in height from 8 to 75 ft., and consist as a rule of two uprights and a stout 8-in. cross-bar. In a few instances standing trees have been utilised as uprights.

The weight of the load has hitherto not been allowed to exceed about 22 cwt. of timber, and though it is possible to send down rough logs of that size, the work has been confined to the transport of railway sleepers and sawn scantlings of different sizes.

The method of working the ropeway is as follows:—

As soon as it is ascertained that all is ready below, that is to say, that the previous load has been removed and the haulage rope clipped on to the empty carriage for the ascent, the hauling rope is detached from the left-hand side of the loaded carriage and lowered on to the rollers below, and the carriage is started, descending at high speed, some 20 miles an hour, to the central station, being kept under control by the brake drum. The two carriages meet here and are stopped at a distance of about 10 ft. from each other, according to the length of the scantlings. The trolley and lever are then brought opposite to the empty carriage, and the cross-bar engages it. The outer end of the lever is pressed down to raise the grooved wheels off the rope, and then pushed forward for a few inches to clear it. The lever is then raised at the end, and the empty carriage, with the hauling rope attached to it, falls downwards slowly, till it is low enough to clear the loaded carriage. The latter is then advanced slowly, and the trolley with the empty carriage comes forward on the rail a corresponding distance, and by means of the lever the carriage is raised and replaced on the rope.

The slow forward movement of the loaded carriage is obtained by means of the brake drum, which is provided with gearing, while the drum is slowly revolved by hand. The carriages are again started, and the arrival of the empty one at the starting platform indicates that the load has reached the foot.

The supporting chains are provided with a hook and ring always placed on the outside, so that they can be released at once when the load becomes detached. The hauling rope is then removed from the clips on the right-hand side, and the up-rope placed on those of the opposite side of the carriage, the same procedure being followed at the starting platform, and the new load is immediately attached, after taking the precaution above mentioned to prevent the premature slipping of the carriage.

The line is kept clear of growth, and the starting platform is so arranged that the central platform is visible from it. Flag signalling is found to be the quickest, easiest, and safest method, and the brakeman is kept in communication with the look-out man on the platform.

This method of transferring appears to be somewhat primitive, involving the use of superfluous manual labour, but, in the opinion of Mr H. H. Gass, it is the best means of working, and is preferable to an automatic arrangement, which, he thinks, would be certain to come to grief continually, and cause both carriages to fall off the rope. The lever arrangement works well and expeditiously.

The loads can be run down at the rate of about two an hour, and the saving is very considerable, so that if it were possible to work throughout the year with sufficient material, this ropeway would show a handsome profit. Its output of work is far in excess of that of the saw-mill, and it can be worked in all weathers.

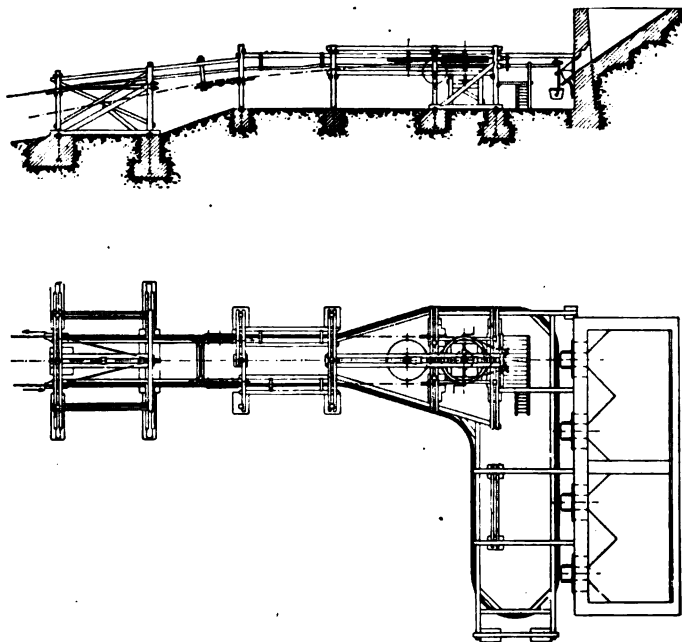
It was at one time feared that damage might be done to the ropeway by wild elephants, as the hauling rope is within their reach in many places, but though they are often on the line, no damage has been done hitherto.

The ropeway has been a great success, but its construction in such a part of the country was beset with difficulties, because of the heavy weight to be moved, and the absence of skilled labour, that available being taken from the aboriginal tribes.

The single rope was adopted in order to save expense, and as the working season is short, and a single rope can easily cope with the quantity to be dealt with, the addition of a second rope may well be deferred for some years until the present rope is so worn as to be unsafe for heavy loads, when it can be used for the upgoing empty carriages.¹

Ropeways Erected by Bleichert & Co.

A typical loading terminal or station by this firm is shown in Figs. 495 and 496. Two arrows at the left of the diagram indicate the direction of the haulage rope, and



Figs. 495 and 496. A Typical Loading Station.

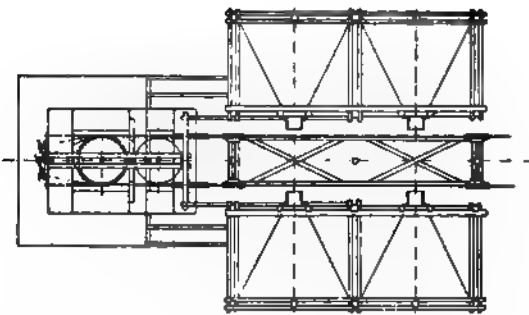
therefore the side at which the empty buckets arrive and the full ones depart. The two rail ropes have their last support at the first cross-beam of the wooden structure, with a diversion to the centre, and are anchored at the second cross-beam, so that the shunt rails start and return from and to this last support. In the third bay, that is between the third and fourth cross-beams, the buckets are automatically uncoupled. Here a man receives a bucket, pushes it along the shunt rails to one of the four outlets of the ore pockets, and when full conducts it to the third bay again, just opposite to where the uncoupling took place, and here the full bucket is again coupled to the haulage rope, and left to proceed on its journey; the man now steps over to the other side again and is ready to receive the next bucket.

The two terminals of a short double ropeway of the Chilian Copper Mine of Catémou are shown in Figs. 497 to 500. The line is worked by gravity, three brakes

¹ H. H. Gass in *Page's Magazine*, August 1903.

being used at the upper terminal to adjust the speed of travel to between 10 and 20 ft. per second. On each of the two rail ropes there is only one bucket, and this is fixed to the rope, and adjusted in such a position that when the one bucket is under the loading shoot of the upper terminus, the other is just over the delivery silo of the lower terminus. As soon as the bucket is full it receives a slight push and descends, pulling the empty bucket up on the other rope, so that the buckets have to be filled alternately from the silos arranged on either side of the top terminal. Although the line is short and of small capacity, it is interesting, as it has a single span of 1,115 m., or 3,657 ft., which is probably the longest single span yet employed.

An unusual arrangement of the terminals of two distinct ropeways belonging, however, to the same colliery establishment is indicated by the diagram, Figs. 501 and 502. The two ropeways connect the collieries in question with an enormous spoil heap,



Figs. 497 and 498. Plan and Two Elevations of Upper Terminal of Ropeway at a Chilean Copper Mine.

the property of a third mining undertaking, and have been installed for the purpose of bringing the spoil to the pits for packing purposes. The spoil is now no longer taken to the top of the heap, but is brought by Talbot self-unloaders and dumped into a row of twenty-two large pockets erected at the side of the spoil heap (see cross section A B, Fig. 502). Each of the pockets holds about 200 cub. yds. of spoil, or together 4,400 cub. yds., which is a sufficient quantity to equalise any fluctuation between supply and demand.

The two collieries are each approximately 5 miles from the spoil heap. The terminal stations of the two ropeways are indicated by squares at the right and left of the plan. The terminals are connected with the hoppers containing the spoil by two suspended mono-rail installations manipulated by an endless rope. The skips are filled whilst travelling at the slow rate of 6 in. per second in front of the exit shoots of the pockets, and when full are transferred to the ropeway stations.

The angle station of an important line resembles somewhat the terminus of a normal

ropeway, with, of course, the exception that the angle station combines in itself the tail terminus of one section of the line and the head or driving terminus of the second section.

Very frequently the second section of the line, or rather its endless hauling rope, is driven or retarded from the terminal drum of the first section; this is especially so if the first section has a sufficient incline to work by gravity, and has sufficient power to spare to operate the second section. Such an installation is represented in the diagram, Figs. 503 and 504. Here the hauling rope of the first or upper section is deflected by a battery of rollers on entering the station, is then led over a pair of guide sheaves on to the terminal drum which has two grooves, and from this the rope passes over an inter-



Figs. 499 and 500. Elevation and Plan of Lower Terminal of Ropeway at a Chilean Copper Mine.

mediate drum and finally on to an adjustable drum for tightening the rope. A weight is attached for this purpose, which hangs in a pit together with the weights which keep the carrying ropes taut. The second and lower section is driven from the same upright spindle which carries the end drum of the upper section. This drum has also two grooves—a similar intermediate drum being intercepted as before—to afford a better grip. The haulage rope of the lower section leaves the station after also passing a battery of rollers.

In smaller installations the same haulage rope runs through the station without interruption.

An angle station for a slight diversion of the line is shown in diagram in Figs. 505 and 506. It is automatic, that is, no attendant would be necessary, as the

buckets will transfer themselves from one rail rope to the other on shunt rails, remaining all the while coupled to the haulage rope which is guided gently round the angle by four rollers on each; the rail ropes terminate at this point, and are kept taut by weights.

A typical example of one form of bucket is shown in Fig. 507. The bucket itself is made as usual of steel sheets with strengthened top edges, and is suspended from a flat iron frame. The bucket is arranged to tip its contents as soon as the lever, shown in the side view, touches a tripper; the point of suspension of the bucket being, as is usual in such cases, slightly below the centre of gravity. The grip or coupling for the hauling rope is here shown above the rail rope as is customary in cases where only gentle inclines are negotiated.

The other receptacles are made to suit the varying nature of the material. These small Bleichert couplings for an upper haulage rope have the advantage that at the terminals, and when negotiating curves, no shunt rail is necessary, as the clips will pass round the guide wheels and terminals. With the haulage rope below the rail rope this would not be possible except with an arrangement similar to that shown in Fig. 508. This diagram shows also a different type of bucket with its accessories, having four rollers. Here the clip is so designed that one portion also carries the pin for the suspension of the frame for the bucket.

It is frequently expedient to transfer mining tubs from their rails to a ropeway in order to place them again on to rails some distance away, as this saves the transferring of the material from the mining tub to the ropeway bucket, and at the terminal of the ropeway back again into tubs. For such purposes of suspending mine tubs, different methods are employed. The one shown in Figs. 509 and 510 consists of one complete carrier with coupling for the haulage rope, and a trailer to support the other end of the tub, the chains with hooks carrying the tub. For larger installations two carriers



Figs. 501 and 502. Combined Loading Station of Two Distinct Ropeways.

may be employed, or complete framework may be used to receive the tub, but the last method naturally increases the weight on the rope considerably.

The ropeway of the Powell Duffryn Steam Coal Co., for the disposal of spoil from their pits, is of interest, as the line has to negotiate several curves. The capacity is 100 carrier loads per hour. Fig. 511 shows part of this line, which is on the Bleichert system.

Figs. 503 and 504. Angle Station.

The Vivero Iron Ore Co., in Northern Spain, has installed five ropeways by the same engineers, for conveying the iron ore from the mines to the seashore, with delivery stations reaching far out into the sea to make it possible to load into ships holding 3,000 tons, which can be loaded in twelve hours. A portion of one of these ropeways is shown in Fig. 512. The receptacles hold 1 ton each, and are conveyed at the rate of 250 per hour, one every fourteen seconds.

A ropeway 35,000 m. (38,000 yds.) long in the Andes Mountains of the Argentine Republic with one terminus at an altitude of 3,500 m. (3,800 yds.), conveys ore which was previously handled by carts at the expense of £2. 13s. per ton, and is now conveyed by the ropeway at a cost of 1s. per ton. There are twenty-five spans of between 320 and 350 m. (350 to 380 yds.) over valleys up to 200 m. (217 yds.).



Figs. 505 and 506. Angle Station for a Slight Diversion of the Line.

This line has weathered the heaviest snowstorms without interruptions. The return strand of the line is used for general merchandise and for conveying drinking water to the mountains.

One of the most difficult ropeways over the most broken country was erected for the purpose of conveying timber from the slopes of Zlatibor in the Black Mountains, and the plains of Zmivrch and Tara, to the river Drina, where it is formed into rafts and floated on the Danube to Belgrade.

This line is at present 6,000 m. (6,561 yds.) long, but will be extended as the clearing of the timber proceeds. There is a gradient of 800 m. (874 yds.), and 18 tons of timber are handled per hour, including stems up to 18 m. (say 20 yds.) long, and of a weight not exceeding 3 tons. The longest span is 790 m. (864 yds.), and the ropeway passes two tunnels of 400 m. (437 yds.) and 26 m. (28 yds.) respectively. At the delivery terminus the timber leaves the rope on suitable shunt rails which extend to a ramp where the stems are taken off and rolled down an incline to the river.

Fig. 513 represents a portion of another ropeway installation for conveying timber from forests, erected by the same firm at Oberaudorf in Bavaria. The length of the line is 600 m. (656 yds.), and has a downward gradient of 340 m. (371 yds.). Six journeys are made per hour, each load consisting of about 4 cub. yds.

Ropeways Erected by J. Pohlig

Mr R. E. Commans has described the construction of a Pohlig ropeway which is at work at the Lake View Gold Mines in Western Australia. This ropeway is employed to transport ore from bins erected alongside the shaft to the top of the 50-head stamp-mill, situated at some distance off on the hillside, to secure the advantage of natural gravitation in dealing with slimes and tailings.

The carriers, like most modern appliances of this type, are suspended slightly below the centre of gravity, to permit of easy tipping and discharge. They are attached to hauling ropes by grips which are thrown in and out of gear automatically, and released at the unloading stations. Ropeways on this system have been erected with capacities varying from 50 to 2,000 tons per day of ten hours. Sometimes when considerable quantities have to be transported a double line is built, although a single line in Lorraine, at Kneuttingen, having a length of about 6 miles, transports some 1,428 tons per day of twenty-four hours. As already seen, ropeways have been carried over longer distances than this, about 20 miles and over having been spanned in different parts of the world.

Fig. 514 is a typical example of a long single span negotiated by this system, the distance between the supports being 875 yds. The ropeway is that of the Brick and Tile Works, Friedrichsgegen, Ems, Germany, the total length of which is 2,363 yds.

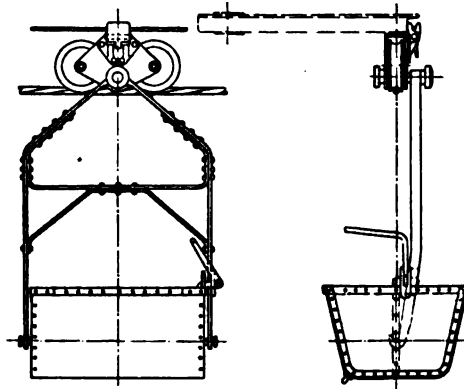


Fig. 507. Bucket Carrier with Haulage Rope above the Rail Rope.

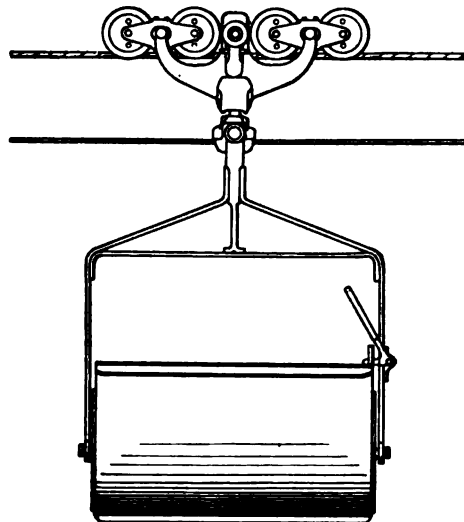
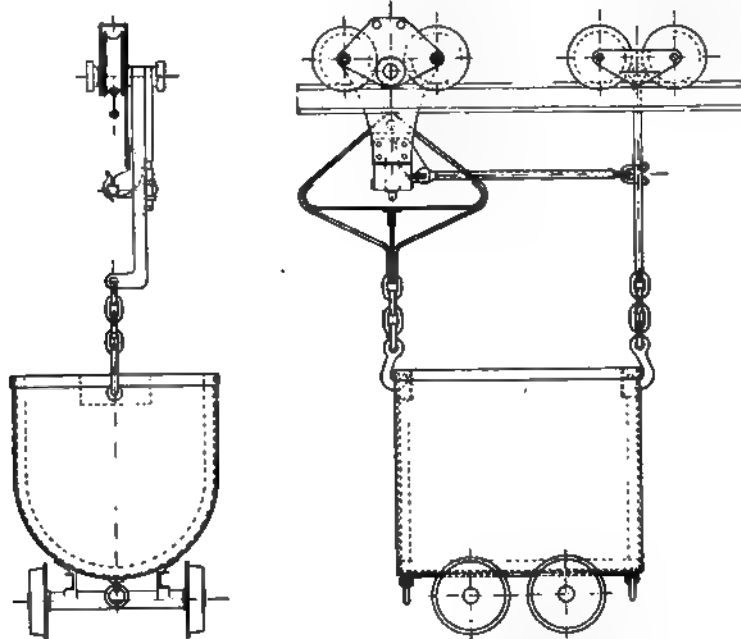


Fig. 508. Bucket Carrier with Haulage Rope below the Rail Rope.

A view of an angle station is given in Fig. 515, at which the ropeway, by describing a curve, changes its direction. It was erected for the Wissener Mining and Smelting Co.,



Figs. 509 and 510. Double Carrier for Mining Tubs.

Fig. 511. Portion of the Ropeway of the Powell Duffryn Steam Coal Co.

near Wissen, Germany. The construction of the angle station allows the carrier to remain on the rope during its passage through the curve without the aid of shunt rails,

thereby dispensing with attendance at this station. The total length of the ropeway is 4,500 yds. It is used for the transport of iron ore.

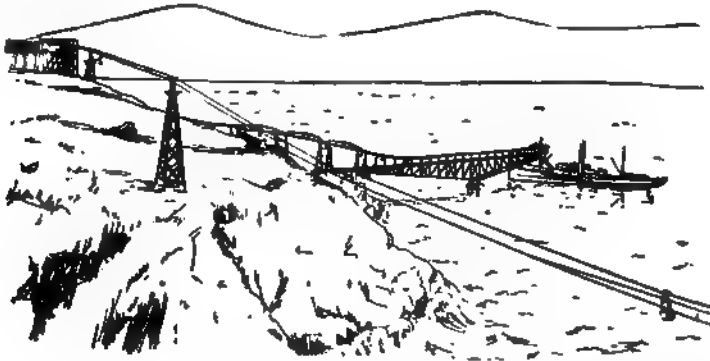


Fig. 512. Delivery Station of one of the Vivero Iron Ore Co.'s Ropeways.

Another view of the same ropeway representing a long span over a river is shown in Fig. 516. The ropeway passes obliquely over a bridge, and is supported by the trestles on the opposite bank. The safety net for the protection of the bridge is also visible.

A portion of a ropeway erected in the Isle of Elba for conveying ore from the mines to the coast is represented in Fig. 517. At the ship loading terminal, which is seen in the distance, the contents of the skips are tipped into vessels.

Part of a ropeway executed for the Dutch Government in Java is illustrated in Fig. 518. This line has been erected for the transport of stones. Its length is 10,000 yds. There is a difference between the levels of the terminals of 123 ft., owing to which a 17 H.P. portable engine is sufficient to drive the line.

An interesting example of a very tall trestle is shown in Fig. 519, which is a portion of a ropeway of the Mount Lyell Mining and Railway Co. in Tasmania.

A portion of a ropeway between the Hilltop Colliery, Durham, and the coke ovens at Malton is illustrated in Fig. 520, which shows an intermediate angle station, the weights for keeping the rope taut being clearly shown on the structure.

Fig. 513. Ropeway for Timber at Oberaudorf.




Fig. 514. Span of 875 yds. of a Pohlrig Ropeway at Ems, Germany.

Colonel S. A. Sadler, proprietor of the Malton Colliery, entrusted the erection of this ropeway to Mr R. E. Commans, who was at that time the English representative of Messrs Pohlig. It is one of the longest ropeways in this country, having a total length of 3,520 yds.

The very fine delivery station of a ropeway for ore in Northern Chile is shown in Fig. 521.

Fig. 515. Angle Station of Pohlig Ropeway near Wissen, Germany.

Ropeways by J. M. Henderson & Co.

An interesting installation, built by J. M. Henderson & Co., of Aberdeen, on the single rope system, was erected in Tasmania a number of years ago. The ropeway is 3,432 ft. long between the terminals, and is used by the North Mount Lyell Copper Co. Ltd., Gormanstown, Tasmania, for conveying copper ore. The capacity is 60 tons

Fig 518. Portion of a Ropeway erected for the Dutch Government in Java.

Fig. 519. Portion of the Mount Lyell Mining and Railway Co.'s
Ropeway in Tasmania.

Fig. 520. Intermediate Tightening Station of the Ropeway between the Hilltop Colliery, Durham, and the Coke Ovens, Manton.

Fig. 521. Delivery Station of a Ropeway for Ore in Northern Chile.

per hour, and the inclines about 1 in 5. There are a hundred buckets in use, supported on eight trestles, the highest of which is 77 ft., whilst the lowest is 24 ft. The illustration, Fig. 522, shows one of the high trestles.

Amongst other installations erected by this firm, perhaps the most interesting is that at Cleve Hill, Shropshire, used for transporting broken stone from a quarry to the railway. This ropeway, which is also on the single rope system, is also one of the longest of its type in this country. It is about 3½ miles in length, and is capable of conveying about 60 tons of material per hour in individual loads of about 10 cwt. The ropeway is arranged in two straight lines connected by means of an angle station. A secondary ropeway, about 230 yds. in length, with a series of short shunt rail sidings, is erected at the quarry for facility in loading the stone into the skips. Storage bins of large capacity are provided at the unloading terminal into which the stone is dumped direct from the skips suspended on the terminal shunt rail. The material is discharged from the storage bins to the railway wagons as required. There are altogether 270 skips in use supported on fifty-five trestles, varying in height from 30 to 60 ft.

Installation by Ernst Heckel

An unusual ropeway installation for the disposal of furnace slag was erected by Ernst Heckel for the Röchling Works at Völklingen in 1910, and the delivery terminal above the spoil heap is shown in Fig. 523. This station is supported by a ferro-concrete mast 3 m., or nearly 10 ft., in diameter, and as the spoil heap grows the station is raised into a higher position. Originally the mast



Fig. 522. High Trestle of the Ropeway of North Mount Lyell Copper Co., Gormanstown, Tasmania.

was 50 m., or 164 ft., high, and in 1912 it was raised by a further 60 m., or 197 ft., giving the mast a total height of 110 m., or 360 ft. The station was, however, not raised to the top of the mast but only to a height of 75 m., or 246 ft., in order not to convey the material higher than necessary. The capacity of the ropeway is 180 tons per hour.

Fig. 523. Ropeway Terminal over a Spoil Heap.

Other important ropeways which cannot be described here owing to want of space, have been erected in this country by Richard White & Sons, of Widnes; The British Ropeway Engineering Co., Ltd., London; and Aerial Ropeway Transporters, Ltd., London.

CHAPTER XXV

AERIAL CABLEWAYS OR CABLE-CRANES¹

AN important development of the ropeway is the aerial cableway, which may be defined as a hoisting and conveying device employing as a trackway a suspended cable generally in one clear span. The term "cableway" as well as the special application of the process is of American origin. The cableway is designed to handle single loads intermittently in a suitable receptacle over moderate distances by means of travelling, hoisting, and propelling lines. The main cable, supported high in the air over its terminal towers, provides a roadway independent of obstructions or the conformation of the ground. It may cross a gorge, valley, stream, road, or railway, depending on no support, except at its terminals. It does not interfere with the passage of wagons, trains, or boats below the cable, so that the work can be carried on simultaneously at several points in the line. Its single engine is manipulated by one man, who may control the whole work of loading, transporting, and dumping, in many cases without the aid of other help.

In its earliest form the cable hoist conveyor was made in two designs, one suitable for downward inclines only, in which the carriage descends by gravity and where one haulage rope only is required; this type is often employed in quarries. The other (the more important of the two) is applicable either to horizontal lines or to lines where the incline is not sufficient for the carrier to descend by its own gravity, in which case the hoisting and conveying are effected by two separate ropes.

The classes of cableways mostly used are of three types; the simplest form being the stationary cableway, having fixed towers at each end. Another form employs travelling towers at each end which can be moved on rails laid parallel to each other; while the third, for radially travelling cableways, employs a fixed tower at one end, and a travelling tower at the other which can be moved over a curved track round the pivoted or stationary tower as a centre.

The limit of span for aerial cableways is about 2,500 ft., although spans of 3,000 have been negotiated. The carriage being secured to an endless line which absolutely governs its movement, may travel at a very high speed if desired, 1,800 ft. per minute or even slightly more—a maximum of 3,000 ft. has been reached in the United States—and the load lifted and conveyed may be up to 20 tons on moderate spans. In this country, however, the most usual speed is from 500 to 750 ft. for travelling, the hoisting speed being about 200 to 300 ft. per minute.

The work performed, in the simplest form, is the lifting of a bucket or skip previously filled by labourers and conveying the load along the cableway to the end where it is dumped by another man. This system is used for trenching, the cableway being set up over and in line with the trench. The material from the excavation is carried back along the line and dumped to back-fill the trench and for similar work. The whole cableway is moved forward from time to time, as the work proceeds.

¹ Extracts from an article by Sterling H. Bunnell on "The Cableway and its Uses," from *Cassier's Magazine*, are embodied in the following.

At the other extremity are the heavy cableways used for wide excavations, the operations performed being the dragging of a huge self-loading scraper-bucket, the hoisting of this bucket when filled, and its transportation and final dumping near the end of the cableway on the spoil bank raised at one side of the excavation. The cableway here comes into direct and successful competition with the heavy boom-derrick doing the same work but with a substantial saving in first cost and certainly no disadvantage in operating expense. Such installations are used for building retaining walls, concrete bridges, dams, and dock work, and not only for removing the material excavated, but also conveying to the workmen the necessary material such as concrete, blocks of stone for building purposes, baulks of timber, steel plates or other structural work.

Any of the well-known forms of automatic buckets to pick up their own loads may be used. Ordinary grabs or "orange-peel" buckets serve to load or unload sand, coke, coal, and any other loose materials from or into boats, stock piles or bins. Dredging of channels, excavating for docks, and similar operations are carried on from solid ground with economy and speed, and heavy excavating buckets or dredges are now used for this work, for which formerly only a steam shovel could be employed. A heavy drag line, operated by a powerfully geared drum turned at a slow speed, tows the bucket along the cableway, the steel cutting edge shaving off a layer of earth, which rolls up on itself in the bucket. When the scraper is full the bucket is hoisted, propelled along the cableway, and dumped at any desired point. The draught may be varied by simply changing the position of the carriage with respect to the bucket; this power of altering the angle of draught is, of course, of great importance, because in this way the bucket can be easily adapted to the character of the material and the required depth of cut.

The cable for such operations is stretched transversely to the excavation as in digging a canal, and the scraper works from the centre towards the side of the channel, dragging up the bank as it fills.

A cableway properly equipped for such excavations is adaptable equally well to work with most forms of bucket, and is thus readily adjusted to the requirements of whatever conditions have to be met.

The designing of a cableway suited to any special requirement needs experience and sound judgment. The main cable is of steel wires, and as great flexibility is not essential, this may be of flattened strands. Lang-lay or locked-coil rope gives a greater wearing surface than the regular twisted-strand rope. The main cable passes at each end over terminal towers, of which the head tower containing the engine is generally higher than the tail tower, sometimes by as much as 20 ft. The cable is securely anchored to the ground, the anchorage being of stone or concrete, and is put in position by tackle-blocks and rope; the usual sag allowed with full load suspended at its centre is about 5 per cent. of the span, the resulting strain on the cable being five times the weight of the carriage and load, plus two-and-a-half times the weight of the suspended cables between the towers. If the proportion of the load and span permit, the sag can be less than 5 per cent., thus allowing a reduction in the height of the towers. Since the strain on the anchorage connections is heavy, and failure of the support very dangerous, the attachment should be most carefully placed; a heavy log may be buried transversely to the cable in a trench in the ground, the main cable being attached to the centre of the log, thus having the log resting against masonry or concrete foundations and undisturbed ground. If so-called "dead-men" are used they may be buried in a mass of concrete if the erection is to be permanent, or attached to a massive anchorage of masonry or concrete with steel rails or beams embedded to distribute the strain of the cable. On permanent work it is

advisable to connect the guys to anchorages separate from the main cable, so that failure of the one need not affect the other. The towers would thus be safe even though the main cable should break away.

The supporting towers are usually of timber in temporary installations, whilst steel structures are used for permanent work, or where timber is not obtainable. A frame timber tower is commonly used for trenching apparatus, with one back and one or two front guys on each tower; for tall towers the main timbers must be spliced and trussed. For more substantial work four posts are used, and one guy at the rear to take the strain on the cable. Steel frame towers are designed like other structures, dispatched in sections, and put together at the site.

Installations with movable towers must have the main cable held taut by counter-weights, or the guys must be shifted from time to time. The moving of the towers is performed by tackle-blocks and line, the main hoisting engine furnishing the driving power. If convenient, the tail of the fall used for moving the tower may be hitched to the hoisting block, and the hoisting drum operated to move the tower. For permanent installations endless chains and separate engines are generally used for moving the towers.

The cableway with travelling towers can perform all the functions of the travelling crane without limitations of reach.

The travelling carriage of the cableway is a simple frame of steel bars carrying two sheaves running on the main cable, and other sheaves over which the hoisting rope runs. Telpherage systems require carriages with framing on one side of the rope only, so that the carriage may pass the towers supporting the main cable at intervals. The sheaves in the lower part of the carriage perform the same functions as the upper block of a tackle, and the hoisting line or lines may be single and directly attached to the bucket, or make any number of turns about blocks to reduce the strain on the lines. As lubrication is likely to be neglected, the carriage should be provided with hard steel axles and good anti-friction bushings for its sheaves.

A few explanatory remarks on the method by which this aerial dumping of loads is effected may not be out of place. The carriage is drawn along the cable by an endless or hauling rope which passes from the carriage over the head tower, and several times round the winch drum on the engine, to secure frictional hold, then back over the head tower to the tail tower, returning to the rear end of the carriage. The hoisting rope passes from the engine over the carriage to the large fall block for raising the load. An auxiliary rope, the dump line, comes from the other side of the same drum of the engine and passes to a smaller block attached to the rear end of the skip. The hoisting rope carries the whole weight of the skip, while the dump line comes in slack but at the same rate of speed. When the bank or other discharging destination is reached, the dump line is shifted to that section of the drum having an increased diameter, and being thus drawn in at a higher rate of speed, the load is discharged.

The most difficult problem of the cableway is the judicious selection of the hoisting rope. The strain upon it, and therefore the sag, varies with the loading or unloading of the bucket. For cableways of short span and for light work a single hoisting line may be led from the drum of the engine around a sheave in the top of the adjacent tower over to the carriage, and down over a sheave to the bucket. Enough permanent weight on the bucket, or bucket tackle-block, is supplied to keep the hoisting rope up off the ground. With this arrangement the hoisting rope must be wound or unwound with the traversing rope to maintain the height of the bucket. The out-haul end of the traversing rope must also support a strain equal to that in the hoisting line in addition to its own initial tension. This strain is generally taken off the traversing rope by

carrying the hoisting line up around a sheave in the bucket block, over a second sheave in the carriage, and on to the tower opposite the engine, in the manner well known in crane practice. This permits of hoisting or lowering the bucket simultaneously with traversing the carriage. The varying strain of the load upon the hoisting line, with the varying sag resulting, is counteracted in one of several ways.

The most usual method is to hold up the horizontal part of the hoisting rope by a series of idler pulleys in carriers running on the main cable. One method of spacing them is by connecting them at equal distances along a rope. The tendency of the slack ropes to foul each other, and the heavy strain on the traversing rope, as they are stretched out behind the advancing carriage, limit the use of this system to slow speeds. Another method provides an extra wire rope carrying knobs or bosses attached at intervals, known as the button rope. The carriers ride on a steel horn projecting from the end of the carriage, and embrace the button rope by jaws or loops of varying width. The buttons are made of regularly increasing size, beginning from the tower across the span. The first carrier to be dropped has the narrowest slot, and is caught by the smallest button, which has passed through the wider jaws of the other carriers without interference. In this way each carrier is taken off by the button corresponding, and the hoisting rope is held up at equal distances by suitable sheaves provided in the carriers.

Fig. 524. Discharge of the Skip of a Travelling Electrically Driven Bleichert Cable-Crane with Man-Trolley into a Portable Hopper for Loading Trains of Trucks.

devised. The button rope is replaced by two smaller lines suspended side by side, and spreading like the sides of a wedge, being held apart by suitably graduated blocks fastened between the ropes. The carriers are partly supported by long rollers resting on both ropes. As the carriage runs out from the tower the diverging differential ropes pick each carrier successively off the carriage. This affords a smooth-running carrier system suited to the highest speeds.

Another system employs trolley carriers running on the main cable and propelled by the traversing rope so that they proceed at some definite fraction of the speed of traverse. The simplest is the half-speed carrier, in which a single sheave in contact with the main cable sheave and with the traversing rope below propels the carrier frame so

In order to avoid the striking of the buttons by the carriers, the patented differential rope system of spacing has been

that it supports the hoisting rope at a point always midway between tower and carriage. This reduction of the unsupported span to one half is sufficient for the successful operation of most cableways, though similar travelling carriages geared to one-fourth and three-fourths speed have been used for unusually long spans. Slippage, if it should occur, causes no trouble, as the carriers are forced together by the main carriage whenever it approaches close to the tower, and are thus brought back from time to time to the common starting point.

Still another system of supporting the hoisting rope is in occasional use. In this an endless hoisting line is provided strained initially to support itself with the same sag as the main cable. At a point on this line there is attached the end of the fall rope which supports the buckets from the carriage. By advancing the endless hoisting line and holding back on the endless travelling rope the fall rope is drawn out and the bucket hoisted. There are at least two objections to this system. The load cannot be hoisted close to the tail tower, as a branch rope leading to the fall-blocks would foul the tower sheaves. With a three or four part line and a high lift this prevents the use of a portion of the cableway. The wear on the hoisting line is as great as on the traversing line since both must slide across their spool drums as they are overhauled, and any attempt at high speed will cause the endless hoisting line and branch fall rope to twist up and foul.

With a single hoisting line, the only practicable form of bucket is a single skip filled by hand and dumped by unlatching it and allowing it to turn over, or lowering it on to inclines which tilt it to liberate the contents, or by setting it down until the chain supporting one end can be unhooked either by hand or automatically, and then hoisted again for emptying. For rapid excavation, dredging, or unloading, self-filling and self-dumping buckets with two hoisting lines are required. One of these lines may lift and the other close an "orange-peel" or "clam-shell" bucket; or one may be attached to each end of the skip, the contents of which are dumped by hauling up one end or letting down the other. The two cables must be wound up together and at the same speed for hoisting, or separately actuated for filling and dumping, so that the manner of operating them in connection with the engine is of much interest. It is evident that the skip may be dumped either by lowering the open end or by raising the other; this may be accomplished by winding both lines on a single drum with special accessories. To dump by lowering one end of the skip the hoisting drum is stopped after the load has been raised, the dumping line is clamped by a steel power brake and the drum is allowed to run down until the skip is inclined sufficiently. The dumping line between brake and drum slackens during the progress and tends to pile up on itself when the drum is again started forward, which might damage the wire rope by bending and crushing where the coils cross. To dump by raising the back of the skip, the dumping line must be wound up at a faster rate than the hoisting line. One way to accomplish this is to provide an enlarged central portion on the drum whose two ends carry the hoisting and dumping lines respectively, and a slotted flange between this portion and the portion carrying the dumping line. By a suitable shifter this line can be thrown against the flange, and entering one of the slots be passed over to the larger diameter where it is wound up faster than the hoisting line on the smaller diameter, and raises the end of the skip as desired.

The limitations on the two systems of dumping just described are that one will only dump while the skip is going down, and the other while it is going up. Further, the available head room between the skip and the top of the spoil bank, or the side of the hopper or railway car into which the load is to be dumped, is diminished by the necessity

of either letting down the skip in dumping it, or leaving sufficient height above to allow raising one end enough to dump the contents. To reduce this lost head room as much as possible the two hoisting lines may be connected directly to the skip instead of carrying them round fall-blocks, and thence to the tail tower. The speed of hoisting is then the same as that of the hoisting rope, and no head room is lost by tackle-blocks; but the two lines must be wound in or out with the traversing line of the carriage.*

The result of the combination is that dumping by clamping the dumping line and lowering the front of the skip must be done while the carriage is stationary, and does not work well for dumping into cars, for either the man in charge of the dumping cannot

reach the skip to guide it, or the skip is brought down within reach, and fouls the dumped material in the car before clearing itself. The other method of winding in the dumping line at a higher speed can be applied only while the carriage is running towards the engine, since the dumping line can only be shifted while winding up. In order to dump near the tail tower it would be necessary to stop the carriage, and, if required, lower the load sufficiently to leave head room for the dumping block. If spoil banks are to be raised at both ends of the cableway, both systems must be applied together with all the attendant complications. These may, however, all be avoided, and aerial dumping easily effected at any point on the line with the carriage stationary or moving in either direction by using similar but separate drums for the hoisting and dumping lines. A standard three-drum hoisting engine thus actuates the complete cableway, the drums being operated together in either direction,

Fig. 525. Electrically Driven Bleichert Cable-Crane with Man-Trolley for Lignite Workings. (The operator has the skip always in view, even when lowering it into a pocket.)

or one or more as desired may be lowered under the control of the brake. This form of cableway engine is necessary for operating self-closing grabs of all types. As such buckets may be found necessary or convenient to deal with all materials encountered in excavating, the use of the three-drum engine is preferable to the method of holding or winding in one line as described. But little extra care is necessary on the part of the engineman in keeping the skip level when using independent lines, as it is only necessary to keep the dumping line well slacked off, the skip taking its own level as it hangs by its chains from the hoisting rope.

A little trouble may be experienced on long spans and with heavy loads from the varying sag of the main cable as the carrier takes up or drops the load. The sagging of

the cable in hoisting increases the amount of line to be wound in. When the load must be dropped on the centre of the span, the cable, if relieved of its load, suddenly flies up in the air; care must therefore be taken to dump the load slowly in order to avoid disarranging the carriage and lines by a violent upward jerk.

With some forms of movable cableways where the distance between the towers cannot be kept uniform, a main cable is provided with a tension equaliser; one method is by pivoting the tail tower at the base, having a counterweight against the tension of the cableway; another method is to employ a stationary tower with a large sheave at its top, round which the main cable is led to a counterweight, but as the bending of a heavy steel cable even round a large sheave is objectionable, the counterweight is better attached at one end to a kind of bell-crank, to the other end of which the main cable is fastened. Yet another method is to connect the end of a cable to a tackle which forms a short portion of the span, the smaller and more flexible cable of which is carried over the tower to a lighter counterweight.

Some balance system is also required where one terminal of a cableway is supported on a barge or float which rises and falls with the tide, and particularly where the cableway inclines upwards from a floating tower to a higher point on shore.

Installations with permanent steel towers movable on parallel tracks may be used for coal storage plants in the same way as bridge cranes are used. A fan-shaped or semi-circular stock pile, reached by a cableway with one stationary tower on the water front, so constructed as to allow the carriage to travel out over the edge of the wall, effects the unloading of scows and barges with very great economy.

Cableways of the Lidgerwood Manufacturing Co.—The cableway has been brought to great perfection by this firm. Their standard type is on the general lines already fully described. The main cable used varies in diameter from $1\frac{1}{2}$ to $2\frac{1}{2}$ in., and ordinarily consists of six strands of nineteen wires each, and the material used may be crucible steel, or a selected plough steel.

The middle and rear wheels of the carriage are generally arranged in an equalising frame, and the fall rope or hoisting rope is supported at regular intervals (as already described in the general remarks) by the Lidgerwood-Miller patent button-stop fall-rope carrier. These carriers also support at the same time the in-haul rope, and where a dumping rope as well is used, these carriers support all three ropes. The latest form of these carriers is made hinged at the top according to Spencer Miller's patent, which equipment absorbs the shock when cableways are used at a great speed. These hinged supports are shown in Fig. 526.

The Lidgerwood cableway steam hoist is equipped with reversible link motion, and the usual form includes two friction drums of large diameter, each being equipped with powerful band brake. These drums may be operated either together or independently, and the ropes travel at the same rate of speed when both drums are engaged; the load may therefore be transferred at a uniform height for any distance along the cable, or raised or lowered at any point along the span. The conveying or traversing rope is carried either on a wide face drum, using separate in-haul and out-haul ropes with fixed ends, which run on or off the drum, or a curved drum is used, around which the conveying rope takes four or five turns to prevent slipping. A typical steam hoist is shown in Fig. 527.

Electrical cableway hoists are now also built very largely by Messrs Lidgerwood; these being of the same general type as steam hoists with respect to drums and gearing, etc. In large and heavy duty cableways the magnetic control with master controller is generally employed; the ordinary drum control being used in the smaller sizes.

Among the first travelling cableways constructed by the Lidgerwood Manufacturing Co. were those used on the Chicago Drainage Canal in 1890, and they proved very efficient, but numerous improvements have since been made. Fig. 528 shows lay-out of cableway used on the Chicago Drainage Canal. A later design was employed on the

Nebish and Livingstone Channels near the Canadian border, being of the general type employed in the Chicago Drainage Canal. On the Nebish Channel work, 1,600,000 cub. yds. of solid rock place measurement were removed by these cableways to an average depth of 15 to 16 ft., and great economy in loading the skips was effected by the use of steam shovels which had a $2\frac{1}{2}$ yds. capacity. The steam cableway skips used were 8 ft. square by 2 ft. 6 in. deep, the weight of the loaded skips averaging 8 tons, and the monthly output of the four cableways so in use averaged 65,000 place yds. In one month 76,752 place yds. were the output allowed and paid for by the Government. This represents an average output of 3,073 yds. for each of the twenty-four days. One of the cableways made a monthly record of 29,490 yds. place measurement. More recent and conspicuous examples of similar installations are the cableways employed in the construction of the Gatun Locks, Isthmus of Panama. Thirteen electrically operated Lidgerwood cableways were employed for that work, eight

Fig. 526. Button-Picking Fall-Rope Carrier, showing the Action of the Shock-Absorbing Carrier Head.

of which, arranged in four pairs, handled the concrete for building the lock, the span in every case being 800 ft., and the loads handled 2 yds. of concrete, or about 6 tons. Similar cableways were used for unloading rock from barges, and depositing the same on storage ground. The span for these was also 800 ft., and each was equipped with a 74 cub. ft. grab bucket.

Cableways may be used for a great variety of other purposes. For instance, the

Onomea Sugar Co., of Hilo, in the Sandwich Islands, have erected a cableway for handling cargo on a rugged coast where vessels often cannot get into the dock. The loads are swung over the small boats by a stationary derrick.

In mining enterprise the cableway has already played no inconsiderable part.

The Ottawa Gold Milling and Mining Co., of Lake of the Woods, Ontario, Canada,

Fig. 527. Lidgerwood Steam Hoist.

employ a Lidgerwood cableway to unload gold ore from lake barges and deliver it over the main line of the Canadian and Pacific Railway to their mill at Keewatin, Ontario. The span of this cableway is about 450 ft., whilst the load carried varies from 2 to 3 tons. A clearance of over 22 ft. is given over the cableway, which is itself 20 ft. above the lake. The tail tower, 75 ft. high, stands on piles driven into the lake, and to these

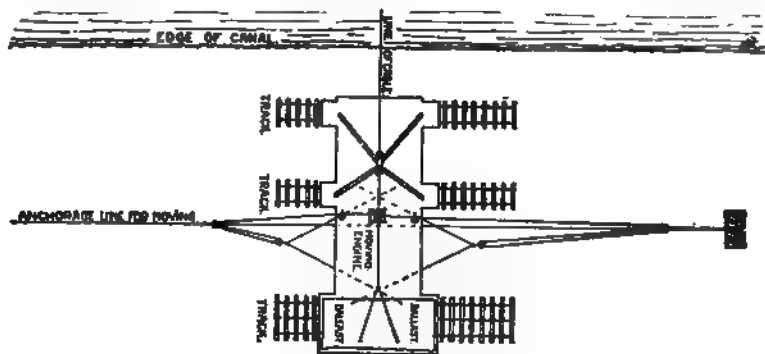


Fig. 528. Showing Lay-out of Cableway as used on the Chicago Drainage Canal.

piles the cable is also anchored. The material is automatically dumped into the ore bins at an elevation of 43 ft., and at the rear of the ore bins is the 80 ft. head tower, from which the operator has a clear view of the entire work.

The barges are moored under the cable between the tail tower and shore. A special feature of this cableway is a bell-hoist installed at the base of the head tower, which is driven from a line shaft in the mill, which is in turn run by water power.

In the construction of marine and semi-marine works, such as breakwaters, locks, dams, etc., cableways have been used with good effect. At Johannesburg, in the Transvaal, the Consolidated Gold Fields of South Africa used a cableway in the construction of a masonry impounding dam intended to store water for the stamp-mills on the Rand. The stone, concrete, and all the necessary material was conveyed and delivered into a ravine about 120 ft. in depth, in which was built a dam of a total length of 500 ft., of a width of 46 ft. at the bottom, and 10 ft. at the top, and of a height of 165 ft. from the bottom of the foundation. This cableway was used nine hours during the day and nine during the night, with only one day lost time in eight months. It regularly fed three derricks with all the building material, and assisted in laying stone during the day. Working at night, the cableway delivered 225 stones for the use of the derricks the following day. The average load was 3 tons. Cableways are much more portable than ropeways, and, if necessary, can be moved considerable distances at no great cost.

Cable Hoist Conveyors by Bleichert & Co.—Fig. 530 illustrates a cable hoist conveyor built by Bleichert & Co., of Leipzig-Gohlis, in which the rail rope is sufficiently inclined to allow the carriage to descend by gravity. One rope only is required in this case to manipulate the hoist, which is used for quarry work.

A hoist of a similar kind, having two principal terminals for unloading, is shown in Fig. 531. Although there is a slight incline, it is not sufficient to allow the carriage to run back on its own account. Two ropes are therefore necessary for the purpose of manipulating it, in addition to the rail ropes.

An installation in which one terminal is fixed, whilst the other can be moved in a circular direction, is illustrated in

Fig. 529. Two Lidgerwood Cableways taking a 20-Ton Locomotive across River.

Fig. 532, while Fig. 533 shows a hoist of a slightly different kind, provided with steel terminal towers mounted on wheels.

As the quay front on rivers and in docks is always costly, new industrial establishments are more economically erected at what might be termed the hinterland, that is, some distance away from the quay, where land is obtainable at a lesser cost. This procedure has become possible by the use of one or another type of conveyor, continuous or intermittent, to bring the raw materials to the works, and to return the finished merchandise for shipment on the quay. One of the appliances frequently used for this purpose is the cable-crane, as its working length is, as a rule, sufficient to reach a building site of lesser value, and the initial cost, as well as that of the working expenses and upkeep, are small.

The above applies equally, though in a different sense, on a coast which might be inaccessible for loading and unloading without the erection of costly harbours or quays. With a cable hoist such structures may be saved. An installation of this

Fig. 530. Inclined Hoist Conveyor, as used for Quarry Work.



Fig. 531. Two-Rope Cableway.

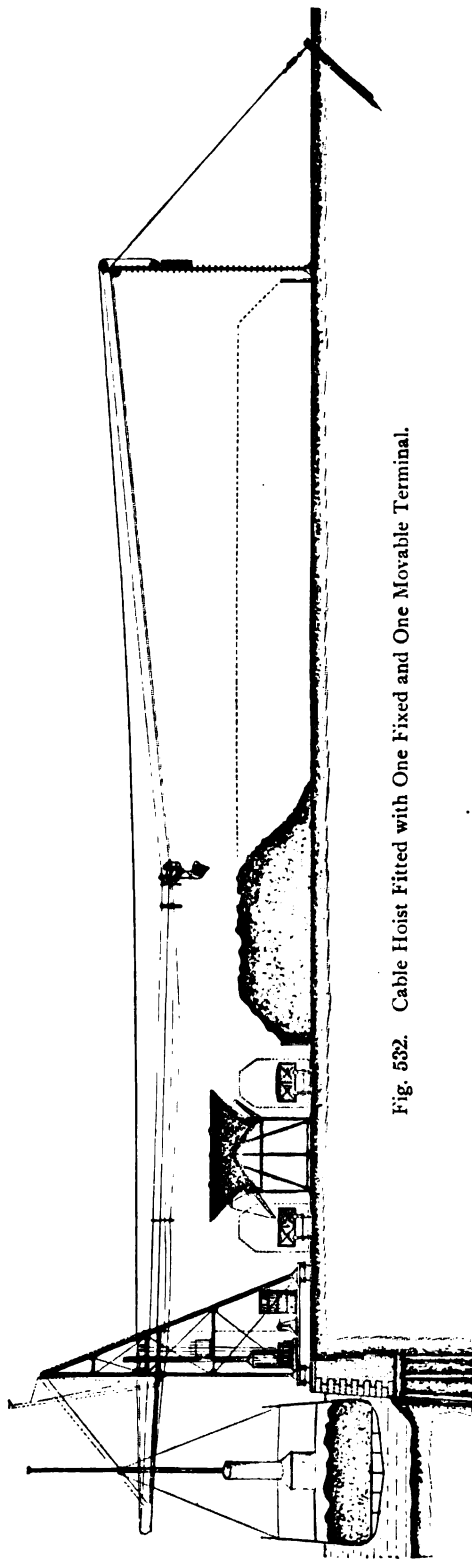


Fig. 532. Cable Hoist Fitted with One Fixed and One Movable Terminal.

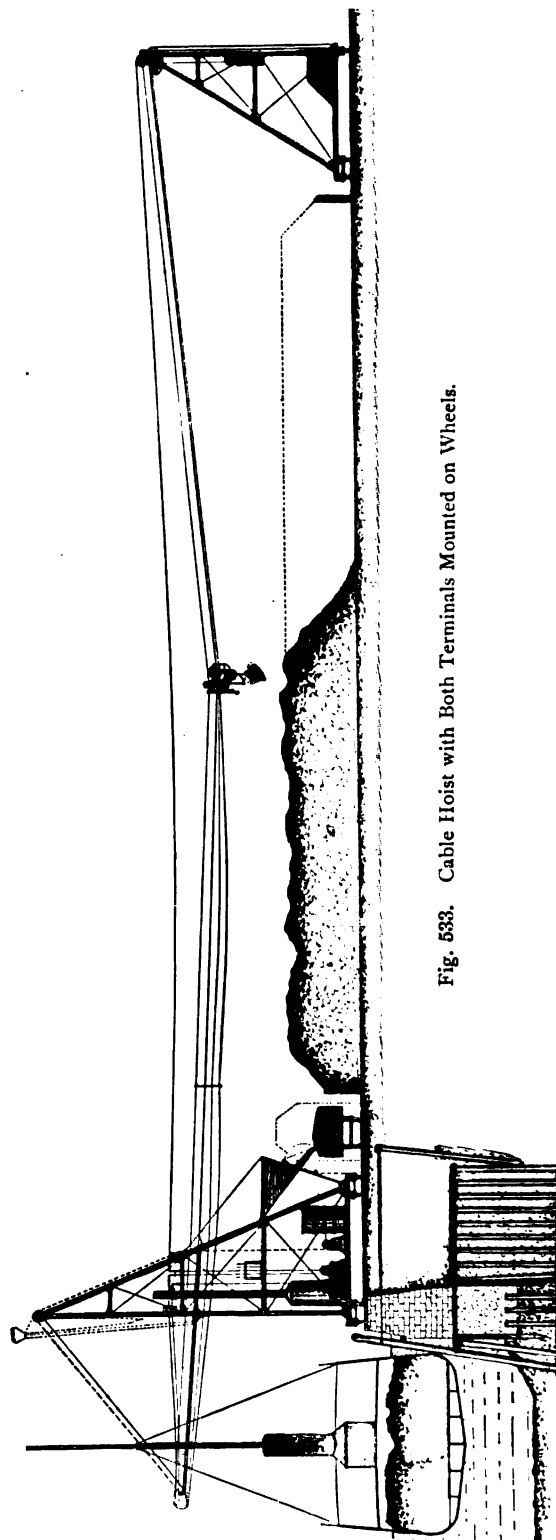


Fig. 533. Cable Hoist with Both Terminals Mounted on Wheels.

latter kind is shown in Fig. 534. It represents a double cableway with which the ore is transferred in skips from the ore pockets at the mine to the ship. The same cable hoist may be used as well for the removing of ballast from the ships as for the delivery of other goods from the ship to the mine. Similar installations may be used for the coaling of ships.

The "Calhoun" Cableway.¹—This is in some respects not unlike the cableways already described. It is built by D. J. Calhoun, of Chicago.

Fig. 535 represents the skip being automatically filled, after being lowered at the correct angle into a heap of coal. It is hoisted by the hauling rope from either of the two terminal towers, similar to Lidgerwood's.

The travelling trolley is conveyed by the hauling rope to a predetermined point, where a catch *x* has been fixed to the rail rope. This locks the traveller in position, so that the skip may be hauled up on the inclines of the stock heap and there filled. When the skip has been raised, the trolley disengages itself from *x*, and runs with its load to the discharging point *y*, where the skip is automatically emptied. In the illustration, points *x* and *y* are shown close together, but these can, of course, be fixed in any suitable position. By means of a second hauling rope the trolley is again conveyed to the loading point, and on its way is arrested by the tripper *z*, which only comes into play at the forward movement of the trolley, and has the effect of so disengaging the fall-block with its skip that it again reaches the stock heap.

The trolley is shown in two views in Fig. 536, and consists of plates *A* and *B*, suspended on pulleys *c* and *d*. Between the plates is placed the sheave *e*,

¹ The Author is indebted to Professor M. Buhle for the following description.

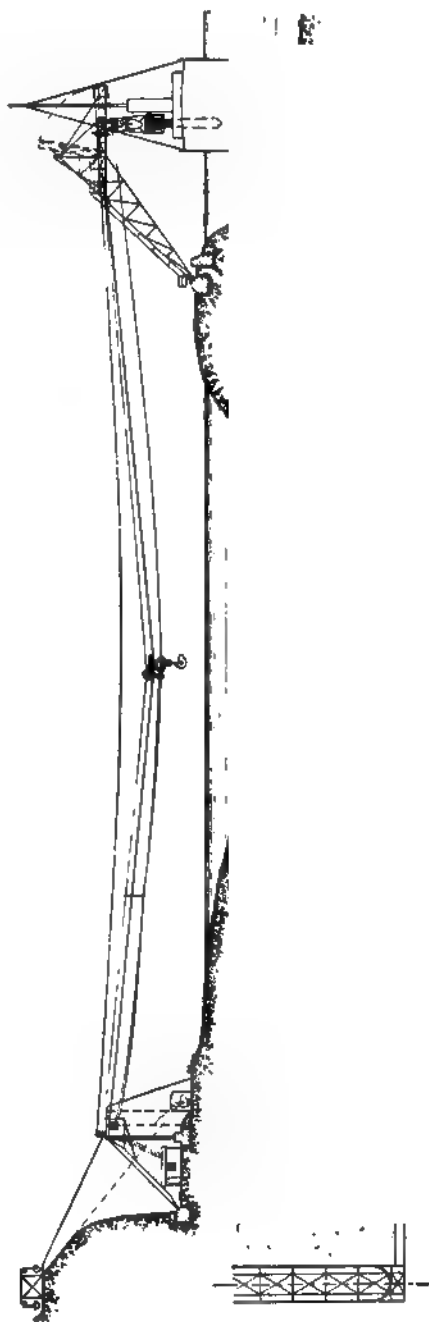


Fig. 534. Cableway for Loading Ships on a Coast Difficult of Access.

which serves to connect the loose sheave and fall-block G with the trolley. When the skip is on the ground, the surface *ab* of the part T, which is movable on the pin F, rests on the guides *cd*, which are attached to A and B, so that the pin *h* of the block G can catch in the recess *b*. If *ab* is resting on *cd*, the pawl L no longer rests on the point *e*, but will engage with the catch X on the rail rope (see Fig. 535), holding the trolley at the point *g*. As soon as the load has been raised, and *h* has thus engaged with *b*, the shield T revolves to the left round the pivot F, while the pawl L, which is controlled by springs, will be arrested at the point *e*, and the hook M releases the catch X, so that the horizontal movement of the trolley can commence. The throw-

Fig. 535. Showing Action of Calhoun Cableway. (For larger view of Tripper, Z, see Fig. 535A.)

off apparatus Y is shown in Fig. 535, and consists essentially of the levers *i*, *k*, *m*. The running trolley strikes against the lever *i*, and at the same time the lever *k* engages the hook H on the skip or shovel bucket (see Fig. 537), and thus effects the discharge of the same. On the return journey the pawl L comes in contact with the tripper Z, which disengages L from the point *e*, whereby the fall-block G is disengaged from the trolley, and the skip dropped through the upward movement of the shield T.

Fig. 535A shows a larger view of the tripper Z. It may be noted throughout that all shocks are borne by the hauling rope and not by the rail rope.

The trolleys are built in three sizes to take skips of 15, 28, and 43 cub. ft. capacity. The corresponding diameters of the main or rail cables are $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ in.



Fig. 535A. Large Scale View of Tripper.

An approximate idea of the capacity and working cost may be formed from the fact that the trolley can make the double journey of a track of 250 ft. long in one minute. At this speed the largest skip can convey over 600 cub. yds. of material in ten hours.

Three men are required to manipulate such a plant, and the coal consumption of the driving engines is said to be 1 to $1\frac{1}{2}$ tons per day under ordinary conditions.

Cableways of John M. Henderson & Co.—In these cableways the carriage or carrier (see Fig. 538) is usually provided with three wheels. These are supported on an articulated frame which allows them to accommodate themselves to any curves the rope may assume.

Some of Henderson's cableways are fitted with a device by means of which the skip can be emptied at any point by the operator in charge. The arrangement for this consists of an additional narrow drum on the winding gear, and a small wire rope between the traveller and the rear end of the skip similar to Lidgerwood's; also special slings, hoisting blocks, and controlling apparatus at the engines.

Fig. 538 represents the usual design of the Henderson traveller or load carriage, and the accompanying numbering refers to the different parts shown in the diagram.



Fig. 536. Travelling Trolley used on the Calhoun Cableway.

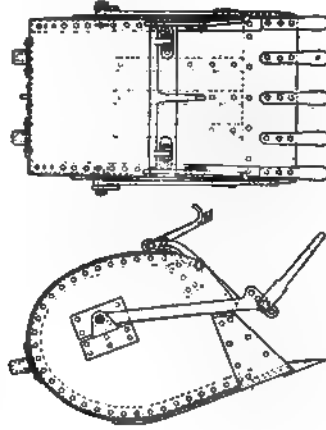


Fig. 537. Skip or Shovel Bucket used on Calhoun Cableway.

Two interesting examples showing the utility of the cableway for different classes of work are illustrated in Figs. 539 and 540.

Fig. 539 represents three Henderson cableways with a span of 750 ft. each, and for loads of 5 tons, the respective heights of head and tail towers being 60 and 50 ft., the engine cylinders having an 18-in. stroke, and being 11 in. in diameter. These cableways

1. Main Cable.
2. Button Rope.
3. Travelling Rope.
4. Hoisting Rope.
5. Load Carriage Wheel on Levers.
6. Load Carriage Wheels.
7. Hoisting Pulley.
8. Hoisting Block.
9. Small Guide Pulley for Travelling Rope.
10. Button-Rope Pulleys.
11. Large Guide Pulley for Travelling Rope.
12. Rope Carrier Pulleys.
13. Pin for Rope Carrier Pulleys.
14. Rope Carrier.
15. Button.
16. Tension Screw and Nut.
17. Oil-Pot.

Fig. 538. Henderson's Load Carrier.

were used by Messrs Pearson & Co. Ltd. for excavating work at the Dockyards, Malta. The terminal on either bank and the progress of the excavating work can be clearly seen. Similar installations have been employed on dock construction at Gibraltar, Hong-Kong, Buenos Aires, and Simon's Bay, South Africa.

Fig. 540 shows a similar cableway with a span of 1,000 ft. for loads of $2\frac{1}{2}$ tons. The

terminal towers are respectively 60 and 72 ft. high. This cableway was erected for the purpose of constructing a viaduct over the Cannington Valley for the Axminster and Lyme Regis Light Railway. The piers of the viaduct were erected without the use of any scaffolding, and solely by the use of the cableway. Some of the piers are 72 ft. in height, and are composed of massed concrete.

Similar plant has been used for the construction of the Vauxhall and Kew Bridges. Cableways have also been used for the erection of viaducts at Kirkcaldy, Durham, and in Devonshire.

[To face page 352.

CHAPTER XXVI

COALING VESSELS AT SEA

By this is meant the transference of coal from a collier to a vessel while under way, or at any rate in the open sea, to avoid the necessity of going into port, whereby sometimes considerable time is lost. When coal can be transferred while the vessel is under way in the direction of her destination, a minimum of time will be wasted, and that solely on account of the speed being slower than usual.

There are two distinct methods of coaling at sea: the first is with the two vessels alongside, which is at all times a dangerous process, and only possible in calm weather. For naval purposes it will therefore never be universally used. The other method is end on, when one of the vessels takes the other in tow at a safe distance, and the transference of coal is made by some form of cableway, and this can be done in practically any weather.

HISTORICAL

Broadside Coaling.—The first test by the British Admiralty in coaling at sea took place in the middle of August 1890, some 500 miles south of the Azores, and 1,000 miles or more from the African Coast, with 2,000 fathoms water under the ships' bottoms. Thus all the conditions of being at sea were amply fulfilled.

The ships that coaled were the "Ajax," "Camperdown," "Audacious," "Iron Duke," "Northampton," "Immortalité," "Aurora," "Neptune," "Conqueror," and "Minotaur." They took varying amounts—in all cases the minimum necessary to take them back to Torbay, some 1,800 miles distant. One ship, the "Howe," evaded coaling, and had to go into Vigo. The rest, although their captains protested strongly in several cases, took coal. There were three full colliers with the fleet, and each ship took an average of 350 tons, at the usual harbour rate, or nearly so. The sea was smooth to look at, but there was a heavy Atlantic swell. Each collier was lashed alongside a battleship, with thick fenders between. Towards the end of the operation the swell increased, and a considerable amount of "moral suasion" was required with at least one collier captain. The coal was taken in in derricks at the main deck ports. One or two ships had torpedo beams broken, and one collier sustained some dents in her side; but no material damage was done. The ships were kept bows on to the swell, and so there was no rolling. All, however, pitched somewhat, and the colliers when they began to get light pitched rather violently. It was this pitching which did such damage as was sustained.

British ships coaling in harbour, where they were completely surrounded by colliers, and working Temperley transporters¹ and whips combined, have coaled 150 tons per hour.

Difficulties of Coaling at Sea during the Spanish-American War in 1898.—Mr Spencer Miller quotes some paragraphs which appeared in the daily press while the conflict was being waged. The *Commercial Advertiser* published on 26th June 1898 the diary of their correspondent, who was on board the United States battleship "Iowa," but only that part is quoted which has reference to the coaling problem.

¹ For description of Temperley Portable Transporter, see page 468.

"June 7, 1898. . . . The collier 'Justine' is alongside, and we started in coaling. The 'Justine' has not the coaling capacity of the 'Merrimac,' but she is a fine steamer, very strongly built. In a seaway this is a great advantage, for though we gave her some pretty hard knocks, no holes were punched in her sides. Since she comes right alongside of our harbour belt, she can be the only sufferer. She is also very convenient to coal from. Working three forward hatches we were able to take aboard very easily 260 tons before supper-time.

"June 8, 1898. . . . Much to our disappointment we find that we cannot get the 'Justine' again to-day, as she was ordered over to the 'Brooklyn,' and we had to content ourselves with the 'Sterling'—to our sorrow. We had every fender out possible, big rope fellows too, that will stand any amount of knocking, but no sooner had the 'Sterling' come alongside than she came up heavily against the side of our ash chute and opened a hole in her side. There was nothing to do but send the carpenters' gang aboard and shove her off for repairs. Every one is disgusted with the 'Sterling' for having sides like paper.

"June 11, 1898. . . . We tried to coal again from the 'Justine' to-day. Made all preparations, and even started sending the coal aboard; but before we got more than a dozen bags on, the ships knocked together again so badly that we had to cast the collier off and give it up again. It is most aggravating, for now we must clean up the ship, only to start in coaling again on Monday."

Thus it will be seen that while coaling was begun on the 7th, yet on the 8th, 9th, 10th, and 11th practically no coaling was accomplished, although each and every day the ships needed coal, and it was most important that they should have it. It may be interesting to know that this same collier "Justine," after discharging a single cargo of coal, was returned to Newport News and laid up a long time for repairs, the bill for which exceeded £200.

It is commonly believed that Admiral Cervera's defeat was directly due to his being short of coal and provisions, which brought him into the harbour of Santiago de Cuba to fill his bunkers. But had he been speedy in coaling after he arrived there, he probably could have escaped from the harbour, because the American vessels were also short of coal, as will appear from the messages exchanged between Admiral Sampson and Commodore Schley and the Navy Department, as they appeared in the report of Captain Crowninshield, Chief of the Bureau of Navigation. The following message was sent from Commodore Schley to Admiral Sampson: "Arrived 21st May off Cienfuegos. . . . Expect difficulty here will be to coal from colliers in constant heavy swell. Other problem easy compared with this one so far from the base." On the same day Admiral Sampson received this dispatch from Commodore Schley, dated 24th May: "Coaling off Cienfuegos is very uncertain. Having ascertained that the Spanish fleet is not here, I will move eastward to-morrow, communicating with you from Nicholas Mole. On account of short coal supply in ships, cannot blockade them if in Santiago. I shall proceed to-morrow, 25th, for Santiago, being embarrassed, however, by 'Texas' short coal supply, and her inability to coal in open sea. I shall not be able to remain off that port owing to the generally short coal supply of squadron, so will proceed in the vicinity of Nicholas Mole, where the water is smooth, and I can coal 'Texas' and other ships with what coal may remain in collier." So much has been said on this subject that it is only necessary to remark that had Commodore Schley been in possession of colliers fitted for coaling at sea, especially during his journey from Cienfuegos to Santiago, there would have been no occasion for his leaving Santiago unguarded a day after his arrival.

French Experiments.—While the Spanish-American War was in progress the French

were making experiments in this problem of coaling at sea. The Paris correspondent of the *Times* wrote on 28th July 1898, in reference to the coaling with the *Temperley* transporter, as follows:—

"An interesting point in these manœuvres has been the attempt to coal at sea. The collier is lashed to the ship, and the ship then steams ahead. A speed of 10 knots is said to have been reached, but other information points to a lower speed by some knots.

"The '*Japon*,' a collier, 3,000 tons, furnished with a *Temperley* transporter, while steaming 6 knots in a rough sea and strong breeze, succeeded in coaling the '*Marceau*' and '*La Touche Treville*' with 200 tons of coal. It was a successful beginning, but the operation was not continued so long as desired, it being interrupted in the case of the '*Marceau*' by way of precaution, and in the case of '*La Touche Treville*' on account of an accident to the '*Japon*,' which had to return to Toulon for repairs. This problem does not seem to have been fully solved, as proved by the damage sustained by the '*Japon*.' The French Admiralty is confident of a decisive result, for it has just decided that the '*Japon*' is to remain permanently attached to the Mediterranean reserve squadron.

"Coaling and revictualling in motion is the question now before all the great navies, and as such experiments cannot be made in the dark, it is certain that all nations will almost simultaneously have the necessary apparatus for coaling ships to be supplied at sea, so that they can be sent to the greatest distance without running short, at the moment of combat, of either food or coal."

Coal Supply.—The Spanish-American War and its lessons furnished the naval officers of foreign Powers with points of interest. For instance, a paper on coal supply was written by the late Vice-Admiral P. H. Colomb, R.N., entitled "Coal Supply, Speed, Guns, and Torpedoes in Naval Marine War."¹ As regards coal supply, Vice-Admiral Colomb said: "We get speed and certainty for voyages made under steam, and the full advantages are reaped in peace time, because coal supply can be exactly arranged for and calculated according to the work required of it, for that can be known; but for the warships in war no such special arrangements and calculations are possible. Coal supply can be treated only generally before the war breaks out. No one can say beforehand whether it has been advantageously or economically allotted."

The difficulties which have been mentioned bear out Lieutenant Bell's misgivings as to coaling from broadside. It is, however, not unlikely that, with adequate means to keep the ships apart, broadside coaling will be neither impossible nor impracticable. One of the latest schemes brought forward is that of Mr A. C. Cunningham, civil engineer in the United States Navy, and Mr William Seaton, of the C. W. Hunt Co., of New York City, by means of which it is alleged that broadside coaling from ship to collier can be effected with impunity. The vessels are kept apart by a current of water pumped from one ship against the other either by special pumps, or by the use of existing bilge pumps. The lashings will be kept taut by means of water jets which are the equivalent of elastic struts. These jets take the place of the fenders, which were, owing to their unsatisfactory work, the cause of the abandonment of broadside coaling. Any breakdown to the pump or pumps might, however, prove fatal to the success of this scheme.²

Concerning the end-on coaling, Mr Spencer Miller made this process his special study, and has read two papers before the American Society of Naval Architects and

¹ This paper appeared in *Cassier's Magazine*, August 1898.

² See end of Chapter XXXIII., "Floating Loading Devices."

Marine Engineers on 16th November 1899, and in 1900,¹ to which the Author is greatly indebted for the following information.

A paper, entitled "Coaling Ships in Squadron on the Open Sea," was delivered by Lieutenant R. S. Lowry, R.N., before the Royal United Service Institution, London, 13th April 1883. In Lieutenant Lowry's plan, special coal boxes or boats holding about a ton of coal were carried by a collier and conveyed to the warship by lines, hoisted on deck, emptied, and returned. These boxes were made buoyant by air-tight chambers. This system was fully discussed, but was evidently not considered practicable.

In 1887 a paper, entitled "Coaling Ships of War at Sea," was read before the same Institution by Lieutenant C. E. Bell, R.N., and was fully discussed by Admiral Boys, the late Vice-Admiral Colomb, Commander Campbell, Captains Fitzgerald, Henderson, and others.

Lieutenant Bell remarked on this occasion that his excuse for putting his views before the Institution would be found in the utterances of Captain Scott, whom he quoted as follows: "I think, moreover, that you require, if you have groups of squadrons, some equal coaling power or means of coaling at sea which we have not yet hit upon." And then he says: "I feel sure that all officers will agree with me that coaling from broadside at sea is impossible, except in very calm weather, and that even then it is attended with great risk to both men and material employed."

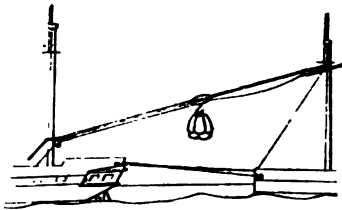


Fig. 541. Diagram showing Bell's Plan for Coaling at Sea.

"I am sure I am supported in such belief by all who have considered the subject, that the only way by which the great difficulties and dangers of coaling at sea can be overcome and the work carried out successfully with the least possible delay, and absence of danger both to men and material, is by coaling from bow to stern." Also, "I do not make any claim to originality—in fact, I believe that the same idea has occurred to many officers who have given any consideration to this subject; and in fact, on

submitting a sketch of the present plan to Sir J. H. Cammerell a short time ago, he then told me it had suggested itself to him some years back, and he believed it was the only way in which it could be done."

Lieutenant Bell's Requirements.—Lieutenant Bell says: "Any satisfactory plan of coaling at sea must satisfy the following requirements:—(1) Rapidity; (2) safety; (3) ability for the ships engaged in the operation to proceed with the minimum diminution of speed (these three requirements are absolutely essential to the success of any plan, but there are others of no little importance); (4) necessity of keeping coal dry; (5) minimum of labour to be employed; (6) little cost for material necessitated."

Lieutenant Bell's Plan.—The plan suggested by Lieutenant Bell is that shown in Fig. 541, in which it will be seen that he first took the collier in tow of the warship, and then added an inclined and elevated cable attached low down to the aftermast of the warship and to the top of the foremast of the collier. To this elevated line a trolley was suspended capable of running along the strand. Two ropes are shown, one fastened to the rear and one to the front of this trolley, the one leading to the warship and the other to the collier. The hawsers, in his system, crossed from the stern of the warship to the bow ports or other convenient places of the collier. He proposed to convey five bags at a time, carrying about 220 lb. of coal per bag. The bags were to be hoisted, by some arrangement not shown, from the deck of the collier to the suspended

¹ See also *The Engineer*, 19th January and 27th July 1900.

cable, and there attached by a man stationed on the foreyard for that purpose. By these means he proposed to satisfy all the requirements he had laid out—namely, rapidity, safety, etc. In referring to the fact that his appliance costs but a trifle, he added: "I would at the same time insist that no expense should be considered too great to carry out this most important—I may say all-important—operation, in those cases where it may be essential to the success or safety of any ship or ships in the Navy, or any expedition that may be engaged in."

Discussion of Lieutenant Bell's Plan.—The discussion that followed was very severe, for, as it will be observed, there were no means provided for maintaining a uniform tension on this elevated and suspended wire, and if the vessels so rigged were pitching ever so little, one of the two following events would occur, and probably both after a short time. By the ships pitching toward each other, the coal bags would be likely to be dropped into the sea, and by pitching away from each other the foremost of the collier would be unshipped or the suspended cable snapped. Commodore Campbell said: "I do not agree with him, but I admire his principle, and I sincerely hope that this paper will help to give another blow to the happy-go-lucky system, and assist us in bringing about that systematic organisation of every detail for which the Navy is now crying out with one voice, and which is now happily receiving the special attention of



Fig. 542. Diagram showing Lieutenant Tupper's Plan for Coaling at Sea.

Fig. 543. Low's Plan for Coaling at Sea.

our rulers." Lieutenant Tupper said, amongst other things: "I think the practice of coaling ships at sea ought to be made just as much a drill and evolution as are many other operations which have to be performed." The chairman of the meeting, Admiral Boys, said in relation to Bell's plan: "But if these ships should get in any seaway whatever, the operation, I believe, must break down."

Lieutenant Tupper's Plan.—Lieutenant R. G. O. Tupper, R.N., submitted a different plan for coaling vessels at sea, as shown in Fig. 542.

His plan provided an endless rope, starting from the stern of the collier in tow of the warship, passing over an elevated support on the foreyard, thence to the aftermast of the warship. This endless rope was to have buckets of coal secured to it at frequent intervals, and the whole was to be operated by a capstan, the coal being thus passed from one ship to another. This plan was of course subjected to the same criticisms as that of Lieutenant Bell, namely, that in any seaway whatsoever the cable would either be dropped into the sea by excessive slack or snapped by pitching in the reverse direction.

Low's Plan.—The Hon. Phillip B. Low secured a patent, 10th July 1893, on a plan practically the same as that Lieutenant Bell described in his paper six years earlier, but with the important addition of a counterweight secured to the end of an elevated carrying cable (Fig. 543).

This counterweight was arranged to maintain a constant tension on the suspended cable, regardless of the motion of the ships. The use of a counterweight to

maintain a constant tension on a suspended wire rope would be successful in any stationary plant on shore. His plan was tested by the United States Navy Department in October 1893. The test took place on board the U.S.S. "San Francisco" and the U.S.S. "Kearsarge." The distance from the shears of the cruisers to the upright poles on the colliers was about 235 ft., hence the distance between the vessels was somewhat less than 200 ft. The transmission wire, as the inventor called it, was secured to the deck of the "San Francisco," supported by a pair of shear-poles at the stern, then run on an incline to a gin-pole at an elevation of about 32 ft. above the foremast of the "Kearsarge," which played the part of the collier, and so gave a gradient of about 8° to the horizontal between the rope terminals and the vessels. After the cable was reeved through the gin-block it was bent backwards, while to the end was secured a counterweight of about 1,600 lb. The bags of coal weighed nearly 200 lb., and the time required to travel from the pole-head on the collier was about fourteen seconds. To hoist and send over ten bags of coal occupied some twenty minutes, giving about the rate of $2\frac{2}{3}$ tons per hour. The Board of Naval Officers were instructed to report on the trial, and their official report was that in rough weather the apparatus would not be of the slightest use in transferring coal from one vessel to another. The apparatus was

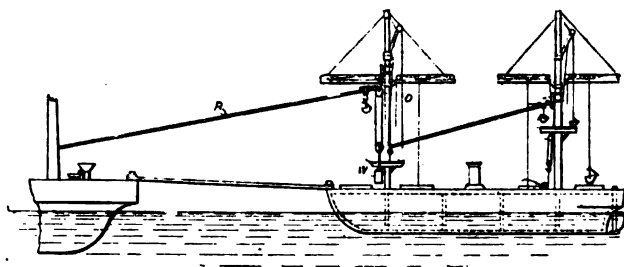


Fig. 544. Diagram showing Walsh's Plan for Coaling at Sea.

reported to have worked well; but as the sea was calm, it was impossible to say what would have been the result in a moderate sea. As the sea became heavier, the distance between the ships would have to be increased for safety, and there would have to be a corresponding increase in the height of the gin-block in order to give a proper inclination to the connecting rope. Presuming that the distance between ships was increased 300 ft., the same angle of inclination preserved, and the same height of shear-poles on the warship, then the gin-block on the collier would have to be 70 ft. above the deck of that craft, as this would reach to the truck of the foremast of the collier. It is clear that to attempt to attach bags of coal at such a height would be difficult, if not altogether impracticable, especially in a rolling sea. Even then the capacity, whatever it might have been at 200 ft., must be something less at 300 ft. distance between the ships. In order, therefore, to increase the capacity of this device, it would be necessary to increase the load; but as it will be noticed that with a 200 lb. load a 1,600 lb. counterweight was employed, a 400 lb. load would require a 3,200 lb. counterweight, while a 600 lb. load would require a 4,800 lb. counterweight, and so on. The element of danger to the ship in carrying any such counterweight would seem to need consideration. If the tow-line should snap, this weight would be pulled up to the gin-block, and as something would then give way, the dropping counterweight would do great damage.

John E. Walsh's Plan.—Fig. 544 illustrates a device patented by John E. Walsh,

of New York. The cable *r*, attached at one end to the towing boat, inclines upwards and bends over a pulley-block *o*, near the head of the foremast, thence bends under the pulley-block *o*, carrying a counterweight *w*. The rope is bent many times, and must therefore carry a very large counterweight to sustain the requisite tensions in the rope *r*. The objections which have been raised to Low's inclined cable and counterweight apply equally well to the Walsh plan.

The illustration also shows overhead derricks for hoisting the load out of both hatches to platforms on the masts, the platform on the mainmast being somewhat higher than that on the foremast, and an auxiliary inclined cable between the masts adapted to carry the coal forward.

Spencer Miller, the author of "Coaling Vessels at Sea," maintains that any hoisting device of this class elevated to any height will be impracticable in a rolling sea. If the load is to be hoisted at all on ships at sea, it should certainly be steadied between guides.

Lieutenant Niblack's Paper.—Lieutenant A. P. Niblack, in a paper on "Coal Bunkers and Coaling Ships," read before the American Society of Naval Architects and Marine Engineers in 1893, presented a most complete argument for the necessity of rapid coaling as a factor in efficiency, giving full data respecting the speed with which the ships then built in the United States could be coaled in harbour. He says: "Our crack ship, the 'San Francisco,' could only take in coal at Sandy Point at the rate of 10 tons per hour, and ordinarily she takes three days, working hard, to fill up. Efficiency in ship's crew must also be supplemented by the best mechanical arrangements practicable, and the coal must be able to go anywhere and to stay there." Coal supply and rapid coaling are in his view most important factors in efficiency, not only in emergency, but also in times of peace, as the time spent in coaling ship is time wasted. He proceeds to give figures representing the average of three or more good actual performances of each ship, and shows that the "Chicago," the "Charlestown," and the "Newark" coaled at the rate of 30 tons per hour. He quotes from the British manoeuvres, giving the average of the "Thunderer" at $17\frac{1}{2}$ tons, and of the "Anson" at 51.6 tons per hour, the latter using the Temperley transporter.

Spencer Miller's System.—His plan, devised in 1893, was to stretch an elevated cable from the stern of the warship to the bow of the collier in tow, one end to be securely fastened to the warship and the other end wound round a compensating engine, similar to the steam towing machines. The load running on this cable was to be conveyed by an endless rope. It was expected that the compensating engine would keep an equal strain on this elevated line irrespective of the pitch of the vessels so connected. In March 1898, Lieutenant J. J. Woodward, Naval Constructor, stationed at Newport News, Va., invited plans and prices for a device embodying much the same general ideas. A few weeks later, in April, a plan was sent to Mr Woodward, and he in turn transmitted it, with favourable recommendations, through the Chief Constructor, to the Secretary of the Navy. It was not, however, until August of the same year that any understanding was arrived at with the Navy Department whereby the work of construction could be begun. The plan, considerably modified, was submitted to a Board of Naval Officers, consisting of Rear-Admiral Ramsay, President; Mr Thomas Williamson, Chief Engineer; and Commander J. L. Tanner. They considered the device "feasible in moderate weather." Thereupon the Department contracted with the Lidgerwood Manufacturing Co., of New York City, U.S.A., to have the apparatus installed on board the collier "Marcellus." So much time, however, was lost in negotiations, that before the work of construction was begun, the war had come to an end.

On 15th October 1898 experiments were performed in New York Harbour with a tug towing a sloop, using a quarter-sized model. Shear-poles were mounted on the tug and blocks on the mast of the sloop, the distance between points of support being 100 ft. An endless rope was employed, being used in accordance with the sketch shown in Fig. 545.

The experiment was performed in a storm, which was so severe that the sloop

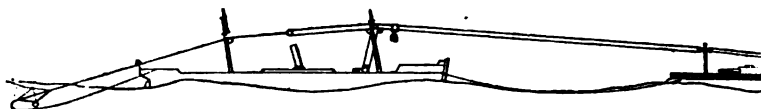


Fig. 545. Woodward's Plan for Coaling at Sea.

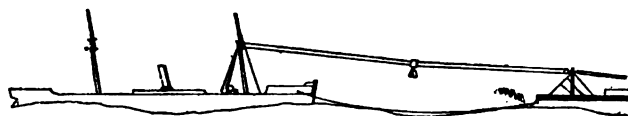


Fig. 546. General Arrangement of Spencer Miller's Plan for Coaling at Sea.

shipped water over the bow, and both boats rolled and pitched very badly. In spite of this, however, the bags of coal were conveyed across the space as though the sea were smooth, the sheet anchor serving efficiently as a compensator, and maintaining a perfect tension on the endless conveying cable. The principle of the "Miller" conveyor, as used on the U.S.S. "Marcellus," is shown in Figs. 546 and 547, but when tested at sea it actually had an additional rope, above the conveying ropes which was led astern, terminating in a sheet anchor. This device is now called the Marine Cableway.

It is intended to be utilised by ships stationed at a distance of from 350 to 500 ft. apart. It might possibly work successfully at a greater distance, but such an experiment has not yet been tried. The vessels are connected by an ordinary cable, and the towing vessel gets under way at a speed ranging from 4 to 8 knots per hour, according to the condition of the weather and the sea which is running. A speed of 5 knots in moderately rough water has been found sufficient to keep the cableway taut and to maintain the proper distance between the craft, unless a tide or some unusual current is encountered.

The appliance which has been fitted to

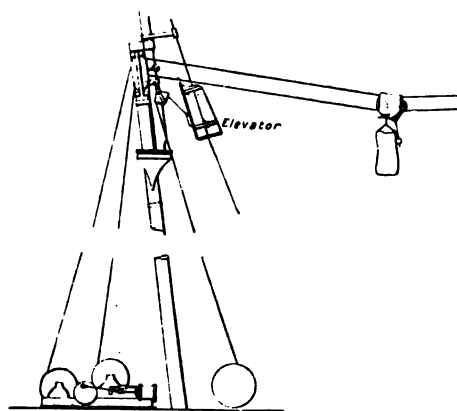


Fig. 547. Details of Spencer Miller's Plan for Coaling at Sea.

the "Marcellus" may be described as follows:—

An engine, with double cylinders and double friction drums of special design, is placed just abaft the foremast of the collier. It has two steam cylinders 12 by 12 in. A $\frac{3}{4}$ -in. diameter steel rope is led from one drum over a pulley at the mast-head, and thence to a pulley at the head of shear-poles on the warship, and returned to the other drum.

The engine moves in the same direction all the time, and tends to wind in both strands of the conveying rope. A novel form of load carriage is suspended from this

rope. It is provided with a gripping device on the upper strand and wheels to run on the lower strand. This carriage conveys two loaded bags, weighing 420 lb. each, suspended from a bail, which hangs in a hook below the carriage. A hoist takes the bags from the deck, lifting them to the mast-head, while the conveyor carriage, coming in from the mast-head, locks itself under the bail. As soon as the bail is released by a man under the trestle-trees, the engine operator hauls in the lower part of the conveyor line. The upper part of the conveyor line is therefore drawn from the rear drum, slipping the specially contrived friction devices. Thus the carriage passes from collier to ship, the tension being sufficient to ensure the bags clearing the water between the vessels. The rope is drawn in at a speed of 1,000 ft. per minute, and if the points of support—mast-head and shear-head—do not vary, the upper strand will be drawn out, under tension of about 3,000 lb., at the same rate of speed. If, however, the distance is increased during the transit of the load, the extra rope called for is given by the slipping of the upper part from the drum. This increases the speed of the upper strand. On the other hand, if the ships reduce the distance between points of support, the speed of the upper strand is reduced.

When the carriage reaches the pulley at the shear-head, it collides with it—at reduced speed—and thus striking, releases the lower hook, and the two bags and their bail drop into the canvas shoot and slide to the deck of the warship. Loads drop in this manner at the rate of one per minute. The empty carriage is drawn back by the rear drum, the forward drum being thrown partially out of friction.

An auxiliary $\frac{3}{4}$ in. rope, known as the sea-anchor line, is stretched above the two strands of the conveyor line, and under a pulley on the carriage. This rope is attached by a "knock-off hook" to the superstructure of the vessel, and rests in a "saddle" on the shear-head, whence it leads through the carriage over pulleys at the head of the foremast and mainmast of the collier, and runs on astern several hundred feet into the sea.

To the end of this rope a drag or sea anchor is attached, made of canvas in the form of a cone. This sea anchor is selected in reference to the speed at which the ships are to travel. In a smooth-water test, speeding at 6 knots, a drag 7 ft. in diameter at the base was used. During the rough-weather trial, the same anchor seemed to give the required tension at 5 knots.

The sea-anchor line is to support the carriage, when empty, on its return to the collier. It permits the conveyor line to be slack, and prevents the overturning or twisting of the carriage. Doubtless at times it helps also to support the load in transit across, but instantaneous photographs taken during the transit of the load show the sea-anchor line slack, thus demonstrating that the tension device on the conveyor line is sufficient to keep the load above the water during transit.

The tests which were made by a Board of United States Naval Officers showed that from 20 to 25 tons of coal per hour could be delivered from the collier to the vessel even when a moderate gale was blowing. The towing vessel, which in this instance was a United States battleship, consumed from 3 to 4 tons of coal per hour. Consequently the amount actually received into the bunkers ranged from 16 to 20 tons, which would be an average of 375 tons in twenty-four hours. It is claimed that such a low speed would not be necessary in regular service, and that the vessels might proceed at a speed of from 8 to 10 knots an hour if desired. However, the consumption of coal on the towing vessel would be largely increased unless the collier could proceed under her own steam. There is a danger, however, that the proper distance to be maintained might then be lessened, whereupon the cable would sag, and thus cause a cessation of operations.

While one of the principal advantages claimed for the system is that a battleship or merchant liner can take coal on a voyage without the necessity of entering the harbour, thus saving time, the process of transferring fuel can also be thus carried out with a minimum of hand labour. One man is required at the hoisting engine, which is very similar to the steam winch now used for transferring cargo on board the large merchant steamships. A squad of twenty men is required in the hold of the collier to fill the bags and deliver them to the deck, while another squad of from fifteen to twenty transfer the bags to the lift. But one man is ordinarily required to do the overhead work, and he is stationed in the trestle-trees of the collier; but for greater safety, two men are employed when the weather is rough and the ship is pitching heavily. The only hands who are required on the receiving ship are stationed at the top of the platform or shear-head to empty the bags into a canvas shoot and return them. There is, of course, a force of bunker trimmers in the hold. In coaling the battleship, it was found that the loads could be transferred at the rate of one a minute without great difficulty, although the rate of loading was somewhat slower, the average being 3 or 4 tons per hour less.

The experiments which were conducted by the American Navy with this system aroused such interest that a number of American shipowners have considered the idea of utilising the apparatus for supplying coal to liners at such points in harbours where the water is too shallow to admit of placing the fuel on board their ships when loaded by the



Fig. 548. Diagram showing the Temperley-Miller Plan for Coaling at Sea.

usual methods. It is understood that further official trials were made with a view to supplying victuals as well as the necessary coal supplies while at sea.

The matter was then taken up in England by the late Temperley Transporter Co., who, in co-operation with Spencer Miller, and without changing the original idea, have paid great attention to the details of the scheme, making various improvements with undoubted success.

The diagram, Fig. 548, serves to illustrate the general principle involved. The collier is in tow of the battleship, being drawn by two hawsers, which are secured along the stern and to the collier well back from the bow.

There is every reason to believe that this apparatus will be an ultimate success, provided that the coal can be conveyed in sufficient quantities, which appears to be the only difficulty.

The principle of coaling at sea under way can hardly be considered as established by the comparatively few experiments already made. It is to be tried off and on for a year or so with various battleships and cruisers, but the final official adoption of the scheme may, however, be considered certain with the above proviso, because of the strategical advantages involved.

Fig. 549 represents the Spencer Miller marine cableway, as used for coaling vessels at sea, and shows the U.S. battleship "Illinois" receiving coal from the collier "Sterling." In this instance the operating winches are placed upon the battleship.

Fig. 550 shows the adaptation of the Spencer Miller method of coaling ships at sea

as used by the Lidgerwood Manufacturing Co. The Russian battleship "Retvizan"¹ is here shown receiving coal from the cruiser "Asia" in the Baltic Sea. The "Retvizan" is equipped with a marine cableway operated by electric winches. This equipment was

Fig. 549. U.S.S. "Illinois" receiving Coal from the Collier "Sterling."

put on after the ship was constructed. The electric winches built are of limited power, owing to want of space, and it is not contemplated to handle more than $\frac{1}{2}$ ton of coal at a time. After the tests were completed, Captain Stchensnovitch, commanding the

¹ This is the ship so heavily torpedoed during the Russian and Japanese War, and finally sunk at Port Arthur, December 1904.

"Retvizan," in a letter of congratulation to Mr Spencer Miller, the inventor, wrote as follows: "Witnessing this last success, I am sure that your system of coaling at sea will be adopted by all the navies of the world. . . . The Trial Board reached the conclusion that the marine cableway works very satisfactorily, and is well worth adoption for general use on board war vessels."

During the Russian-Japanese War ten of the largest battleships and cruisers of the Baltic Fleet were fitted with marine cableways similar to that installed upon the "Retvizan," to enable the fleet to coal at sea in their journey to the Far East. These

Fig. 550. "Retvizan" receiving Coal from the Cruiser "Asia."

cableways permit the ships to be 300 ft. apart in a smooth sea, and 800 ft. apart in a rough sea. At this distance, however, the loads have to be reduced to half a ton.

G. Lene's Plan to Keep Ropes Taut.—His method to take up the slack of the rope, and pay it out if necessary, is as follows: The conveying rope descends from the mast-head of the coal receiving ship over an apparatus resembling a hydraulic cylinder with plunger and multiple sheaves, similar to that used in manipulating lifts, except that it is for compressed air. After the rope has passed over the sheaves of this apparatus it ascends again to the mast-head, and returns to the winding engine of the collier. If the distance between the ships is reduced the plunger of the pneumatic

device is forced out, which separates the multiple sheaves and thereby takes up the slack, and in the reversal of conditions the plunger is driven back in the cylinder by the extra tension, and the necessary extra length of rope is paid out. The apparatus is capable of keeping the rope at the same tension between the limits of the maximum and minimum distance between the vessels. There are obvious, if not serious, objections to this, viz., that the rope must pass over eight or twelve comparatively small sheaves, which is not good for the rope, and also adds to the driving power consumed. Such a coaling appliance has been experimented with in the German Navy, and found capable of transferring 50 tons of coal per hour.

The Adam System.—This differs essentially from the Spencer Miller system in that

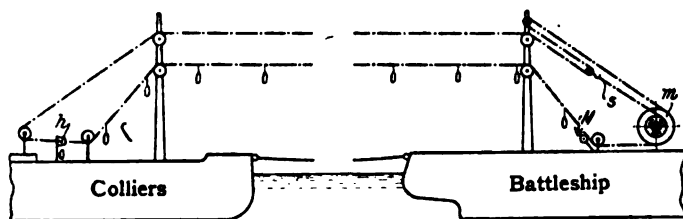


Fig. 551. Diagram of the Adam System of Coaling at Sea.

it is continuous, whilst the latter is intermittent, that is to say, the cable which conveys the coal from ship to ship is, in the Adam system, continuously running in the same direction, the sacks of coal being attached to and removed from the rope at the respective terminals, whilst it is in motion; whereas in the Spencer Miller system the rope makes a reciprocating motion, that is to say, it conveys a bundle of sacks of coal from the collier to the battleship and returns empty for another load. In the earliest form of the Adam system the cable was attached high up from the mast of one vessel to that of the other, and was kept taut (at the collier end) by passing up and down over a series of rollers.

The Adam system as now in use is represented schematically in Fig. 551, which shows the sacks of coal attached singly at point *h*, and after passing three sheaves they are cut off at *m* by a stationary knife. The cable returns over driving pulley *m*, forming a bight over snatchblock *s*, thence back to the collier. The cable which is attached to the snatchblock *s*, and which keeps the continuous cable taut by paying out or drawing in rope, is manipulated by a small drum keyed to the same spindle as that on which the driving wheel *m* is running loose. The action of paying out rope or taking up slack is probably the most important detail of the scheme, just the same as it is in the Spencer Miller system, but here it is achieved by entirely different means. The main pulley *m* (see Fig. 552), which is the driving terminal of the rope, is coupled together with a system of magnets of an electro-motor, while the rope attached to the snatchblocks is secured at the other end to the drum *c*, which is driven from the anchor of the electro-motor. If now the motor is started to work, the system of magnets with the wheel *m* is turned in one direction, while the anchor with the drum *c* turns in the opposite direction. The magnet system will, however, revolve continuously, while the anchor will only revolve until the drum *c* has wound up the slack of the rope, and therefore tightened the endless cable. If the sea is smooth and the vessels proceed at the same distance apart, the endless cable will be kept in motion by the pulley *m*, as the electro-motor will

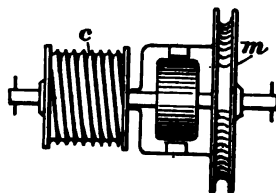


Fig. 552. Arrangement of the Tension Drum.

then work like a normal motor in the ordinary way. If, however, the distance between the masts of the vessels should become greater, so that the endless rope becomes tighter, the extra tension thus caused will overcome the resistance of the motor, and will permit the drum *c* to unwind some of the rope until normal tension has been re established, when the winding drum *c* will again be stationary. On the other hand, if the vessels should approach nearer to each other and the endless cable should thereby become slack,

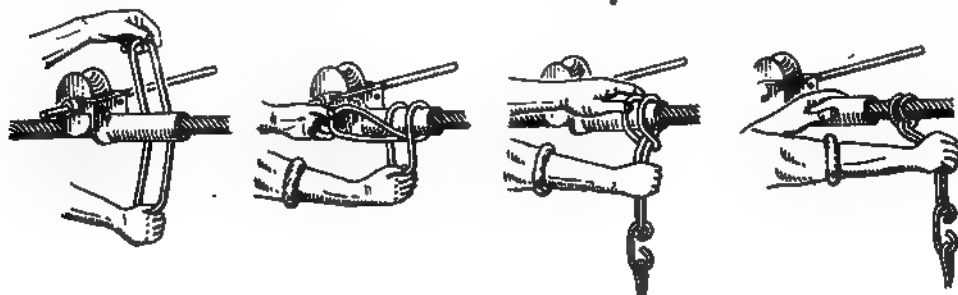


Fig. 553. Showing Method of Attaching Sacks to the Cable.

the drum *c* will automatically wind up the slack until the tension is again normal. The coal sacks are attached to the cable at *h*. Here the endless cable passes through a piece of tube, to one end of which a roller is secured which runs on the cable. This apparatus is fixed to the deck of the collier by a spindle passing through the roller just mentioned, so that any side motion of the cable will permit the arrangement for the attachment of the sacks to move with it. The method of attaching the sacks is as follows:

Each sack is fixed by a sling loop of strong cord, about a yard long (see Fig. 553, which shows the operation in four stages). As soon as this is adjusted over the sleeve, it is pushed off the sleeve on to the cable, the weight of the sack immediately tightening the sling loop on the cable. Since the sacks are thus tied to the main cable by pieces of cord, it is difficult to negotiate the two sheaves on the mast, and the difficulty has been solved in the method which will be seen from Fig. 554. The sheave has a flange only on one side, and the two auxiliary sheaves have also only one flange each, so that the rope is held in position at one side by the flange of the large sheave, and at the other side by the flanges of the two small sheaves. Permanently fixed to the large sheave is a covering for the lower part of this sheave, which has a horn-like extension at the one side; this keeps the sacks at the front side of the sheave, and prevents the cords from becoming entangled with any part of the sheave. The empty sacks are returned in the same way on the return strand of the cable in bundles of 10 to 40 sacks. They are put on to the cable and cut off, exactly similar to the full coal sacks. The capacity of this coaling-at sea installation is about 120 tons per hour. The Adam system was adopted by the German naval authorities after some £75,000 had been spent in experimenting.

Fig. 554. Coal Sack Negotiating a Sheave.

Latest Developments.¹—Considerable success has attended the experiments under the Navy Department of coaling at sea, the latest demonstration being with an

¹ From the "Army and Navy Register" (Washington), 17th May 1913.

improved type of the Lidgerwood-Miller marine cableway. In the latest experiments, which were conducted as an acceptance test of the contractors' equipment, the naval collier "Cyclops" was used in conjunction with the U.S.S. "South Carolina," and the test was conducted on Saturday, 12th April 1913.

The contract of the Navy Department with the builders of the system called for a delivery of 480 tons of coal in a period of eight hours. The mechanism was operated for six hours under most unfavourable conditions of weather, and was pronounced a success. The test was conducted for four hours, or long enough to convince the naval board that the system would answer all the purposes of the service. The transfer of coal from the "Cyclops" to the "South Carolina" at sea in a driving rain, with the collier rolling 20°, was preceded by a dock trial. The test was observed by a board composed of Captain Thomas Snowden, in command of the "South Carolina"; Naval Constructor L. B. M'Bride, of the Bureau of Construction and Repair; and Lieutenant Halsey Powell, of the U.S.S. "South Carolina." Under this improved system of coaling at sea all of the gear is installed on the collier.

The plant includes an automatic tension engine, and even the mast necessary to erect on the coal-receiving ship is carried, when not in use, on board the collier.

In order to attach the load to the cableway carriage all the lines are hauled down to the deck, and a group of bags hooked on. The haul-down gear is then released and the conveying engines set in motion to convey the load. This load travels at very high speed, attaining a maximum of 3,000 ft. per minute. The load carriage is provided with an automatic tripping device. When the load arrives over the deck of the battleship it collides with a bumper block which actuates this automatic trip, thus releasing the load. Before the load is released the cableway is let down at the battleship so that the bags of coal are dropped only a few feet.

The regular winches and regular gear of the battleship are used to lower the bags to the battleship's deck, making it possible for a collier to tie up to any battleship, and coal. The fuel is delivered at the rate of five or six bags, carrying 700 to 800 lb., on each trip, or a total delivery of 3,500 or 4,000 lb. The rate of delivery is from 50 to 60 secs. in a distance of 500 ft. between the collier and the battleship, which in the recent test were steaming at the rate of from 7 to 8 knots. The maximum amount of coal transported within an hour during this test was 83 tons.

On board the battleship some difficulty was encountered in taking away the coal from the forecastle on account of the driving rainstorm. The cableway was frequently stopped in its operation to enable the men on the battleship to clear away the coal. In spite of these difficulties, however, more coal was transferred than ever before, and justified the opinion, freely expressed by naval observers who witnessed the test, that the cableway was capable of a delivery of 100 tons per hour. It was also observed that the best record was in the last hour of the test, which showed that the machine did not have a fatiguing effect upon the men.

An important feature is the automatic tension engine, designed and constructed to meet the demands of the Navy Department. This engine, in connection with the marine cableway, has supplanted the sea anchor. It maintains the supporting cable at the requisite tension and deflection independently of the speed of the ships. After the cableway is set up and the engine adjusted for the required tension it needs no further attention, other than oiling, throughout coaling operations.

The automatic tension engine¹ is a single drum horizontal engine, having 10-in. by

¹ This was fully described in an article by the Author, which appeared in *Cassier's Magazine*, November 1916, entitled "Oil Fuel Bunkering at Sea."

10-in. cylinders, and capable of maintaining a strain of approximately 3,000 lb. The drum is 20 in. in diameter by 23 in. face, and connected to its shaft through the medium of springs allowing a limited rotation of the drum on the shaft. Changes of tension in the rope cause this drum to rotate to a limited extent. This motion of the drum operates through the medium of a nut, screw, or lever. A controlling valve regulates the amount and pressure of the steam supplied to the cylinders. These changes in tension in the rope are communicated to the steam supply to the cylinders in such a way that the rope will be paid out or taken up as demanded. That is to say, an increase in tension causes a reduction of steam pressure, permitting the rope to overhaul the engine and restore the tension to normal, while a reduction of tension causes an increase of steam pressure, thereby causing the engine to take up slack and thus restore the tension.

The conveying ropes for moving the load along the main cable are operated by two automatic tension engines of smaller power than those for the main cable. These are high speed engines, having the spring drum mounted directly on the crankshaft. One of these engines operates the in-haul rope, the other the out-haul rope, pulling in opposition to each other. The automatic control compensates for the lengthening and shortening of the conveying lines as in the main cable tension engine. In addition to the automatic control, the controlling valves can be manually operated.

The manual operating gear of the two engines is interconnected and controlled by a single lever. When this lever stands vertical (mid-position) both engines have the same in-pulling power, so that the load remains stationary on the cable. When this lever is moved in the direction in which the load is to travel, the inpulling power of the engine controlling motion in said direction is increased, while the inpulling power of the other engine is decreased. In other words, one engine overhauls the other when the load is in transit.

In the test which took place on 12th April, the tension of this engine was 17,000 to 18,000 lb., and never showed the slightest disposition to slacken nor unduly tauten the main cable.

Oil Fuel Bunkering at Sea.—Without discussing the merits or otherwise of oil fuel, its employment has the decided advantage that it can be bunkered comparatively easily. The United States Navy have designed their battleships for the last ten years exclusively for the use of oil fuel, and our own battleships of the "Queen Elizabeth" type are also so fitted. In one harbour in the Caribbean, outside of the Canal Zone, a stock of 10,000 tons of oil fuel is permanently maintained by the United States, an amount about sufficient for the supply of a division of oil-burning battleships of the "Arizona" type.

It has been suggested in America that the oil should be bunkered by the marine cableway, like the coal, and that it should be taken over in tanks holding a ton; but as it is much easier to have a hose communication between the vessels, which need not be high up out of reach of the water like the coaling cable, but can be low down, the idea has never been exploited. The British Admiralty, says Mr Spencer Miller (a pioneer who has twenty years' experience with the marine cableway), have mastered the art of oil bunkering at sea, and the apparatus is carried on their own oil-tank ships.

While refuelling at sea, a towing speed of at least 10 knots is required. In 1906 the British Admiralty coaled at sea at a speed of 11 knots. The tank steamer "Petroleum" transhipped oil at sea at towing speeds above 12 knots. The method they employ is practicable when the sea is smooth, and is illustrated in Fig. 555. In 1912, *Shipping Illustrated* says, in the issue of the 2nd November: "The operation of bunkering at sea while steaming at a rapid rate is regularly carried out by way of training. . . . Other

nations have now adopted this method, which is very effective, but needs great care in seamanship and no little practice."

The British battleships tow the oil-tank ship. One hawser tows, and a secondary line supports the oil hose by hangers at frequent intervals. This plan was tested by United States ships with a small hose. The tank steamer "Petroleum" carries 900 ft. of 5-in. diameter flexible bronze hose, weighing 9 lb. to the lineal foot, a total of 8,100 lb. The distance between ships is about 600 ft. The greater portion of the hose drags in loops in the sea (see Fig. 555), and this results in longitudinal strains which tend to damage the hose. The loops are also apt to gather down against the bow of a towed ship, which affects the towing, and they form sharp bends which may shorten the life of the hose. Eighty tons per hour are thus transhipped. The United

Fig. 555. Method of Oil Fuel Bunkering Underway, as Employed by the British Admiralty.

States Trial Board, testing this method between the fuel ship "Arethusa" and the destroyer "Warrington," used a 2½-in. hose. They reported the difficulties substantially as mentioned above.

Fig. 556 indicates diagrammatically an improved arrangement for supporting the oil hose while transshipping oil at sea. The same sized automatic tension engine and carrying cable used in the marine cableway are required for a proper support of the oil hose free of the sea. An oil hose supported in this manner permits oil bunkering to be carried out in heavy seas. The automatic tension engine furnishes the necessary elastic medium for paying out and taking in the supporting cable as demanded by the motion of the ships. It maintains a uniform tension on the supporting line, and prevents any lashing or whipping of the hose while the operation is being carried on in a heavy sea. The weight of the 5-in. metal hose and the oil to be supported by the suspended cable is double the weight of the carriage and coal-bags of the marine cableway.

The necessary tension in the supporting line would be the same in both instances. The oil hose is a uniformly distributed load; the bags of coal a concentrated load frequently in the centre of the span.

The automatic tension engine now installed on the collier "Cyclops" will develop a tension of 18,000 lb., and will sustain a 5-in. flexible bronze hose and a 1-in. diameter steel wire rope on a span of 600 ft. with a deflection of about 58 ft. The rear mast of the "Cyclops," with its heavy pulley block secured to the mast-head for coaling at sea, is also needed for oil bunkering at sea. The collier "Cyclops" carries oil fuel and

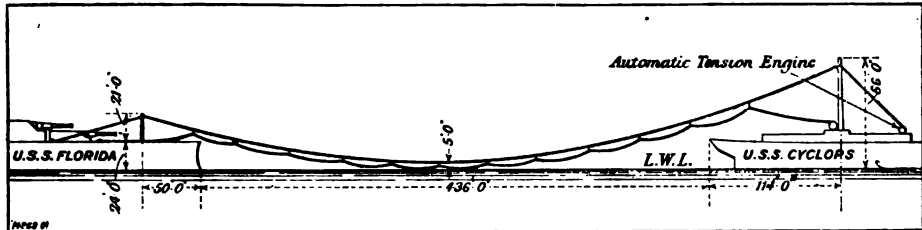
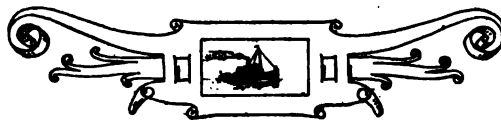


Fig. 556. Diagram showing Improved Method of Oil Fuel Bunkering at Sea.

coal. Several of the United States battleships burn both kinds of fuel. The "Cyclops" can deliver either fuel if provided with a suitable oil hose, reel, and oil pumps. The time required for setting up and taking down the hose would be reduced, and all damaging strains in the line minimised.

The automatic tension engine above described, and the Adam tension winch, perform successfully what the sea anchor failed to do. Piston (be it pneumatic, hydraulic, or steam) or weight compensation with block and fall have proved to be impracticable, as they do not allow sufficient latitude, which, in the opinion of Mr Spencer Miller, should not be less than 20 ft. Besides, there are other inherent weaknesses into which we cannot enter.



CHAPTER XXVII

MONO-RAILS AND TELPHERS

NARROW gauge railways in industrial establishments are being rapidly superseded by the more convenient mono-rail, whilst the telfer is making a slow but sure inroad into works of greater magnitude.

MONO-RAILS

Two-rail surface tracks on which the vehicles are propelled, either manually or by horses or locomotives, are very much in the way of other traffic, especially in congested passages and factory rooms. The overhead mono-rail from which the vehicles are suspended occupies space which is of lesser value, and in many cases conditions obtain which involve the absolute necessity of transport at a considerable height from the ground, and there is a good deal to be said in favour of suspended overhead traffic. Some of the introductory remarks in the chapter on Ropeways also apply here. Among the obvious advantages of this system are the following: mono-rails being out of the way of other traffic, remain clean and unobstructed, and therefore offer less resistance to the movement of the vehicles, and the latter, having generally only two wheels, run more easily than four-wheeled receptacles, as the friction is reduced. The condition of the ground, whether even or otherwise, does not influence the construction of a mono-rail system, and the floor is unobstructed by rails, turntables, etc., whilst the vehicles can either be suspended sufficiently low for a man to push them whilst walking on the ground, or so high up that they do not interfere with other traffic, or with obstructions, such as plant or machinery, on the ground.

The track may be supported from the ceiling or other part of the building, or from constructional iron or wood work. It may negotiate sharp curves and gradients, adjusting itself to most requirements. In small installations the track may be a light rail of selected section, or may consist in its simplest form of a flat iron bar, the vehicle being suspended from a two-wheeled trolley upon these rails. If the point of suspension is too high above the ground for manual propulsion, cable or electrical haulage may be resorted to, or the line may be so laid as to work by gravity if it is only required to transport goods in one direction. For large installations the rails are of more substantial section and the supporting girders are correspondingly heavier, a suspended locomotive being frequently used to pull the train of vehicular receptacles.

TELPHERS

The ideal form of mono-rail traction is the telfer; the name signifies the application of electricity as motive power to vehicles on a mono-rail. (Telfers are, however, driven by oil or petrol motors, where electric energy is not available.) The credit of the invention of the telfer is due to Professor Fleeming Jenkin, M.Inst.C.E., who died in 1885. The name was chosen by him, and is derived from the Greek *tele*—far, and *pherein*—to bear, to carry. A telfer consists of a suitable bogie or trolley, running

on an overhead rail track, and supporting in a suspended position a receptacle to carry the load. The bogie or trolley is fitted with and propelled by an electro-motor which collects its current by a small trolley pole from the single, double, or triple overhead conductors, arranged alongside and supported on the track structure.

There is no limit to the distance of travel, and the telfer may either be a man-telfer, that is, accompanied by an attendant, who from his cab starts, stops, lowers, or dumps his load and returns for a further one; or it may be so arranged that all movements are automatic, so that the telfer with its load, when released at the loading terminal, travels automatically to a predetermined position, dumps its load and returns empty to the starting point for a new load. Some of the man-telfers are fitted with one or two electric winches to pick up or lower loads at any point on the line, and in order to save labour some are so constructed that the attendant can lower himself or rise with the load to detach or attach it on the ground.

Automatic telfers have been perfected to an astonishing degree. They are provided with a perfect automatic block system, the passing telfer establishing its own electric connection, so that no second carrier can enter the line within a predetermined distance of that in front; and if one is stopped for some cause or another, all the succeeding ones will stop at the same distances apart. To give a full description of the intricate electrical fittings would occupy more space than is available.¹

Telfers may also be divided into the real mono-rail type, in which the machine travels on a bulb-headed rail secured to the top of an I-beam, and into the bottom flange type, often called transporter. In the latter type the running wheels are duplicated in number, and travel on both sides of the bottom flange of an I-beam. It will be at once realised that these differences are very important, while with the renewable top rail the whole of the rolling load is in perfect balance above a vertical centre line, whereby it is possible to travel with safety at higher speed, and the axles of the wheels run in bearings on either side and are therefore more positively held, being in double shear. With a bottom flange machine, on the other hand, the axles of the wheel are in single shear, being cantilevered. It is also obvious that with this duplex nature of the track formed by the bottom flange of the beam, curves cannot be negotiated so readily. In spite of these limitations, most serviceable machines are built on this latter system.

It might be summed up that the mono-rail telfer is more suitable for heavy loads, say over 1 ton net load, and for greater speeds of travel, while the bottom flange machine or transporter is more suitable for loads up to 1 ton, and for slower speeds of travel, both having their field of utility.

Telfers for large and bulky loads are fitted with a trailer, or double telfers are used, either direct connected or geared; the latter is generally the case where an excessive gradient has to be negotiated. The speed of travel varies from 4 to a maximum of 20 miles per hour, according to the nature of the load, the capacity required, and the gradient of the track.

The track may lead over buildings and across rivers. It is sometimes bracketed to the sides of buildings, at others supported on the open land on A-brackets. The load can be switched on to branch lines over track switches, which the telfer man himself operates from his cab. The telfer man can also reverse his machine at will, open and

¹ Automatic telferage is fully dealt with by A. J. Wallis-Taylor in his book, "Aerial or Wire Rope-Ways"; also by Dr P. Stephan in "Die Drahtseilbahnen," an English translation of which has been prepared.

close doors, run the entire length of the storehouse or shop, and pick up loads without any previous preparation. In and out handling from the works is equally well performed by the same telfer, and there is no limit as to distance.

Mono-rail telfers have been more particularly applied to gas and electricity undertakings for the purpose of handling the large quantities of coal and coke which have to be continuously dealt with in such works, and are employed in nearly all the largest gas and electricity works in this country, also in some on the Continent. These appliances seem to be particularly applicable where the duty is heavy and continuous, and where the route to be traversed is anything but in a straight line, and also where branch runs have to be made off the main road.

These telfer machines are usually designed to travel upon a single rail, which is generally bolted to the top flange of rolled steel girders of suitable depth and flange width—according to the span between the available supports. There may be as many curves and branch turnouts as are necessary—the design of the machines being such that any reasonable curve can be negotiated with ease and safety.

They have been built for dealing with loads up to 4 tons, but there is no reason why heavier loads should not be dealt with if the necessity arises.

The lifting speeds range from 60 ft. per minute with heavy loads, to 200 ft. per minute with light loads and long lifts. The travelling speeds may be anything from 500 to 1,000 ft. per minute, according to the nature and length of the run.

Telfers by Strachan & Henshaw, Ltd. (Figs. 557 to 562).—With these telfers the whole of the load is carried on four manganese steel wheels, which are built in pairs into swivelling bogie trucks, the trucks being each pivoted independently into the main hoisting frame by universal joints. These universal pivot joints are practically frictionless, and do not depend for strength upon any pin connection. The load is directly supported solely by heavy mild steel interlocked stirrups, which have ample freedom and flexibility. The result is that all twisting strains liable to be set up, and due to the surging of the load, or sharply negotiating the curve in the track, are entirely eliminated from the main frame and bogies, and from the swivel connections between them. The four travelling wheel axles are mounted in roller bearings which are built on to the two steel bogie trucks.

The bogie carries the whole of the travelling mechanism complete with the motor; the latter is connected to two travelling wheels by a silent link chain, which forms a triangular drive between the motor pinion and the two spur wheels keyed directly to the two wheel axles. The motor is so mounted as to permit the tightening of the driving chain. The second bogie carries the other two ungeared wheels, and also the rear C-hanger for supporting the outer end of the hoisting frame. The C-hanger is a solid mild steel forging, and is freely pivoted in the wheel track, as well as at its connection to the main frame. The two bogies are connected together above the track level by a substantial coupling bar with pivoted ends.

The hoisting gear, complete with motor, is built into a rigid frame composed of rolled steel H-girders or channels, all parts being carefully balanced about the centre line, so that when it is suspended from the bogie trucks the whole frame hangs plumb and level with its centre of gravity directly under the centre of the track.

The hoisting barrels (twin drums for long loads, and single drums for grab or bucket) are placed with their axes parallel with the track, and so disposed laterally that the centre of the ropes or chains falls exactly in line with a vertical line through the centre of the track.

It will thus be seen that the whole load is perfectly balanced about the centre of the

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Figs. 557 and 558. Telfer for Conveying Coal from Barges to Coal Store or Boiler-House.

track, and is all applied directly on the centre of the running rail. This ensures smooth and steady running at high speed, with a very small amount of wear and tear on both wheels and rail.

Figs. 559 and 560. Telfer for Handling Coke from Gas Retorts.

Figs. 561 and 562. Telpher for Handling Two Skips.

A cabin for the operator is attached to the under side of the main frame; a seat is always provided for the driver, and the controller brakes and emergency switch, etc., are all placed within easy reach. The starting resistances are also placed within the cabin, as a rule, though sometimes it is found convenient to vary this arrangement. For working in the open or in dusty situations the cabin is boarded right up; for ordinary indoor work, however, the cabin is left open, with just sufficient guards to prevent the driver falling out.

The type of machine shown in Figs. 557 and 558 is generally used for conveying coal from barges to coal storage ground, or boiler-house bunkers, and any automatic grab or bucket can be used with it.

The telfer shown in Figs. 559 and 560 is generally adopted for gasworks duty. This machine has been developed more particularly for the purpose of handling coke,

Fig. 563. Telfer Conveying Raw Material to the Stock Shed.

hot or cold, from all types of gas retorts—horizontal, inclined, or vertical—and has been successfully applied for this purpose in many gasworks.

An arrangement, as shown in Figs. 561 and 562, is adopted in smelting works, where it is often found convenient to carry the load of ore and fuel at the same time, so that on each journey a properly proportioned charge may be carried to the furnace. The same machine is also suitable for dealing with long loads, such as timber baulks or metal bars up to 30 ft. in length.

Automatic Telfer Installation by Adolf Bleichert & Co.—This interesting example is for a chemical factory, and is remarkable on account of the adaptability of the line to the existing conditions. The raw material is unloaded from barges by means of a crane and grab, and transferred to a hopper from which the cars of the telfer are loaded. The cars electrically block each other automatically, and thus stop before the loading point until the preceding car has been dispatched, when they will automatically advance

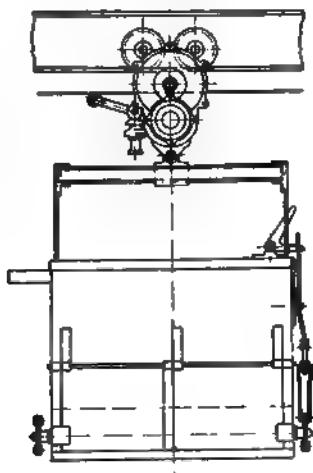
Fig. 564. Method of Withdrawing Material from Stock Shed.

Fig. 565. Telfer Car Negotiating an Incline.

to be loaded. The raw material is carried to the stock shed, as shown in Fig. 563, where it can be discharged at any desired point. Winch cars run on the same

Fig. 566. Telfer Cars Delivering into Storage Shed.

track to rehandle the material (see Fig. 564). These lower the empty buckets to the ground level of the shed, and pick up and carry the loaded ones to the factory where the material undergoes the process of manufacture. A ropeway with a total length of



Figs. 567 and 568. Telfer Skip with Bottom Door Discharge.

5,000 ft. was also installed here for the purpose of handling the finished products. The cars for this are filled at the loading point whilst suspended on a mono-rail, and run under electric power to the foot of an inclined section of the track. Here they are drawn up to the height of the rails in the roof of the shed by the rope, to which they couple

automatically, and again release on reaching the top (see Fig. 565). The telpher cars then cross the factory yard on a long elevated bridge at the end of the finished product storage shed (Fig. 566), in which they travel along three tracks connected by switches. As with the line for raw material already described, the discharge can here also be effected automatically at any desired point of the storage shed. After this the telpher cars again return automatically to the loading point, and the process is repeated.

A telpher skip, with bottom door discharge for handling coke, also built by the same makers, is represented by the diagrams, Figs. 567 and 568. It is considered that such a mode of discharge is less likely to injure coke or coal. The same appliance is made with and without a winch; in the former case the skip is lowered on to the coke or coal heap before the bottom doors are opened. The arrangement of the locking of the two doors is such that they are automatically released on the lever at the upper end coming in contact with the tripper.

Hitherto the automatic electric telpher was almost a German monopoly, but it is now being built in this country by the Mitchell Conveyor and Transporter Co. The first installation on this system was built this year for the Imperial Paper Mills, Gravesend.¹

¹ Described in Cassier's "Eng. and Ind. Management," 11th August 1921.

CHAPTER XXVIII

HANDLING RAW MATERIAL IN CONNECTION WITH BLAST-FURNACES

FURNACE HOISTS

ORDINARY elevators are not serviceable for feeding blast-furnaces, the ore, limestone, and coke being too irregular in size, and each of these three materials must be handled separately, and in different proportions, and in addition to this the feeding must be more or less intermittent; all these conditions call for an elevator of a different type to the bucket elevator. The older appliances were ordinary platform lifts, similar to those used for passengers. The ore, after being weighed in tip trucks, was pushed on the lift and taken to the top of the furnace, and then tipped into it.

Modern furnace hoists consist of skips on wheels, which are raised on rails up a sharp incline to the top of the furnace, into which they automatically discharge their loads.

These skip hoists, not being automatic and continuous, require some hand labour, however little it may be, for the purpose of filling the bucket at the lower terminal, the discharge at the other terminal generally being automatic. A single skip hoist will do excellent service where it is necessary to raise occasional loads to a considerable height, as for the service of blast-furnaces. For this purpose elevators are almost universally used, and generally go under the name of furnace lifts or hoists. It is rarely now that one meets with the old-fashioned vertical hoist or lift. There are certain accessories to modern furnace hoists which greatly increase their efficiency. For instance, the opening of a slide is all that is necessary for the purpose of filling the buckets when they are ready for a charge, and it is in these accessories (on which the efficiency of the elevator more or less depends) that a great many ironworks are still very far behind. It is not an unusual sight to see the iron ore heaped up with a shovel and filled into small gauge railway trucks which are pushed by hand to the lift, an operation which requires a large gang of men for loading and moving the wagons to and from the platform of the lift. Even if a modern elevator has been introduced, the full benefit will not be felt until the appliances conveying to it are automatic and mechanical.

Therefore, in erecting installations of this kind, more or less automatic, it is most important that the whole plant should be worked in such a way as to be one mechanical installation divided into two sections, namely: that for conveying the material to the hoist, and the hoist itself.

It was in the United States that mechanical appliances for this purpose were first introduced, and many of the larger up-to-date furnaces are now fitted with devices of this class. It is essential that such elevators should be built in a very substantial manner, as breakdowns would stop the working of the furnace, with possibly disastrous results. The elevators are mostly so arranged as to obviate manual labour at the point of delivery at the top of the furnace, and the material, be it iron ore, limestone, or coke, is taken up a skip-load at a time and emptied automatically into the furnace. It

is also essential that the feeding device which admits the material into the furnace should be so arranged as to distribute it evenly, and at the same time to do so without allowing the gas to escape.

The general construction of these elevators consists of an inclined iron-trussed bridge upon which the rails for the ascent and descent of the skips are laid, whilst the hoisting gear for their manipulation is laid on the ground level. The rails, when they reach the upper terminus, are generally bent into a more or less horizontal position, so as to tilt the truck for unloading purposes. In addition to this, the back wheels are supported either by rails that are bent at the terminus, or else they have a different diameter on either side of their flanges, so that during the ascent the skip runs on its normal wheels, whilst at the terminus the larger diameter wheel engages with short lengths of extra rails and thus assists the automatic clearance.

To balance the dead weight of the skip a counterweight may be used, or a double track may be employed, so that the empty skip will descend on the one track whilst the loaded one is being drawn up on the other. In such a case the distributing hopper on top of the framework must have an elongated form, in order to take the charges alternately from skips on either track.

Another plan which has been recommended is to lay the two tracks above each other, and to run one skip on the upper and one on the lower rails. The two will pass each other at about the centre of the bridge, where there will be plenty of room for them to clear each other. At the terminals, that is to say, at the loading and discharging points, both will be in a suitable position for filling and discharging.

The difference in the capacity of the skips, of course, depends a great deal on the system on which the furnaces are worked and on their capacity. In the Brown Hoisting Machinery Co.'s apparatus the capacity of the skips is generally 2 tons of ore or 1 ton of coke, while the cubical capacity is 110 ft., and the hoisting speed 300 ft. per minute.

The time occupied in raising the load to a furnace 80 ft. high would be 20 secs.; discharging it takes 4 secs. and returning it 10 secs., or 34 secs. altogether for each cycle of operations.

The speed at which the skip travels is 5 ft. per second, which, if no counterweights are used, would require a motor of about 100 H.P.

Another estimate is for a motor of about 150 H.P. for a skip of about 150 cub. ft. With a skip of a capacity of 240 cub. ft., intended to serve a furnace of 550 tons daily capacity, the service would require ninety charges (which would each take two skiploads of ore and lime and as many of coke) in twenty-four hours; 360 ascents would therefore be necessary, and only four minutes could be given to each turn, including the filling of each skip.

Furnace Hoists of the Brown Hoisting Machinery Co.—Fig. 569 represents a typical installation of a furnace elevator as designed by the Brown Hoisting Machinery Co.

The stock of iron ore, coke, etc., required for use during one day is kept in large pockets, constructed of wood, iron, or concrete, at the foot of the elevator. The main stock pile is kept on the open ground in the stockyard, and from this the pockets are replenished with the material to be used immediately. The material which has been brought by rail or from a distant part of the works is conveyed along an elevated railway and down an incline into the store pockets. The trucks which are used for this purpose are hopped to both sides, and discharge their load through two longitudinal hinged doors on each side of the truck. One of these trucks can be seen in position on top of the pockets in the illustration.

The details of a storeyard must, of course, in a great measure depend on the conditions under which the material is received.

The skip of the elevator receives its charge from one of the three hopper-bottomed pockets. A weighing machine is provided so that a record of each charge can be kept. As soon as the skip is full it is hoisted, and its contents emptied into the furnace. The hoist is electrically driven, and the electro-motor is placed in a cabin shown in the illustration.

The emptying of the skip is effected in the following manner: The ordinary rails, on reaching the entrance to the furnace, are bent in a level direction so that the front wheels as soon as they reach this position proceed horizontally, whilst the back wheels, or rather that portion outside the flange, engage with a second pair of rails which are laid close to the ordinary track, and proceed in the same direction as the latter. The skip then rises until it has reached an angle of 45° to the horizontal, when it automatically discharges its contents, as shown in the illustration, where one of the skips is depicted in the position of unloading.

Fig. 570 shows a portion of a similar installation in which the skip is approaching the furnace top. One of the rear wheels with flange in centre is clearly visible. In this case the rear wheels engage with two short lengths of rails which are slightly further apart than the main track, so that the rear wheels proceed in a straight line. The main rails have been bent over a short distance in a horizontal direction, which gives the skip the unloading position shown in the illustration.

Fig. 569. Typical Furnace Elevator.

The hoist cable runs over guide pulleys placed at the top of the furnace, and the cable is manipulated by an electrically driven winch in the cabin below. The descent of the skip is utilised to evenly distribute the feed from the hopper to the furnace, by causing the former to revolve. To this end the apparatus is provided with a very ingenious mechanism which only comes into operation as the skip descends. After every charge deposited into the hopper the latter is turned round a few degrees, to give the delivery of the next load in a different direction, and thus in turn the loads are distributed in all directions in the furnace.

This faculty of evenly distributing and thus mixing the material without the use of manual labour is usually deemed one of the great advantages of such furnace elevators, because the even distribution of material over the whole surface of the furnace is a point of great importance.

Furnace Hoist of J. Pohlig.—Figs. 571 and 572 illustrate the blast-furnace elevator at the Iron and Steel Works, Hoesch, Dortmund. This installation was erected by J. Pohlig, of Cologne, and has been successfully at work since 1901. It is erected at an incline of 53° to the horizontal. The skip has a capacity of about 4 cub. yds., therefore holding about $1\frac{1}{2}$ tons of coke, or about $3\frac{1}{2}$ tons of iron ore, and is operated in a similar manner to that already described.

Fig. 570. Portion of Furnace Hoist of the Brown Hoisting Machinery Co., showing Skip in a Discharging Position.

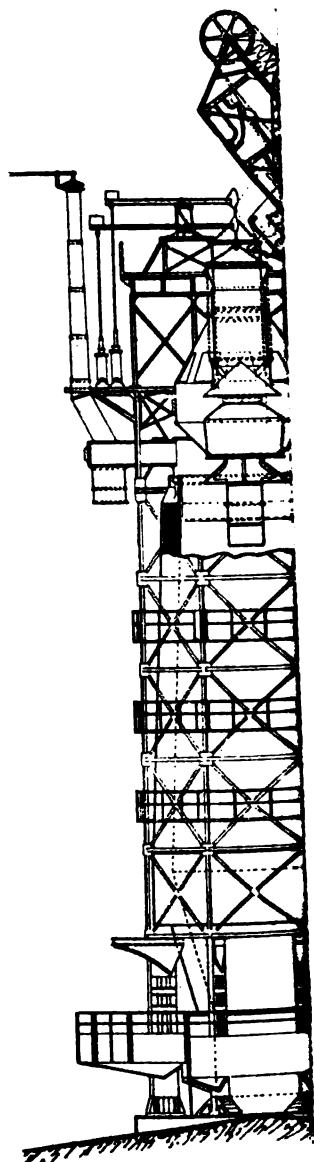
The speed of travel is at the rate of 150 ft. per minute when ascending, and at the rate of 250 ft. per minute

when descending, so that sixteen to twenty journeys are hourly accomplished.

The illustration shows the driving gear in a raised position. This consists of an 85 H.P. electro-motor, which is coupled to a winding gear. There is, however, a second motor standing by which can also be coupled to the winding gear in case of a breakdown.

Behind the motor-house is a receptacle for the coke, which is either conveyed to it by means of narrow gauge trucks, or is brought by tipping trucks on the low level.

Furnace Hoist of Palmer's Shipbuilding Co.—One example of the American elevator applied to British furnaces is that illustrated in Figs. 573 and 574, which



represent the Brown hoisting and automatic distributing gear applied to the new furnace of Palmer's Shipbuilding Co. at Jarrow.

So completely automatic is this arrangement that one man can entirely control the hoist. The inclined structure is built of steel. All the bearings of the rotating parts are of the dust-proof pattern, fitted with large and easily accessible oil cells. The mineral distributor is substantially built of cast iron, and is actuated by a pinion keyed on a shaft which, by a suitable gearing and clutch, is connected with the main hoisting machine, and this in such a way that when the skip is ascending, the clutch is out of gear. When, however, the skip is descending, the clutch is thrown

Figs. 573 and 574. Furnace Hoist of the Palmer Shipbuilding Co.,
Jarrow-on-Tyne.

in gear, and turns the distributor several degrees. The proportions of the skip are such that four full loads constitute a charge.

The capacity of the skip is 120 cub. ft., and the hoist equipment is capable of handling 1,300 tons of material per day. The skip is built of steel plates, elliptical in section, and is fitted with a false steel plate lining on the inside, so arranged as to be easily renewable.

The hoisting engine is of non-reversible type, with double cylinder, 12 in. in diameter, with 15-in. stroke, and is equipped with hand friction brake and a powerful friction clutch.

In order that the hoist operator may at any time be able to ascertain the exact

height of the burden of the furnace for the purpose of preventing under or over charging, four rods are let into the top of the furnace through suitable openings, and the rods are connected with dials situated in the hoist operating house, so that as they are lowered into the furnace they indicate the exact height of the stock.

Another indicator fixed up in the cabin consists of a graded dial connected to the bell by a light wire rope. Its gearing is such that a drop of 1 in. of the bell corresponds to a 3-in. pointer deviation on the dial. There is also an automatic indicator for

Fig. 575. Lürmann Furnace Hoist.

signalling the number of skips from each charge, the latter being indicated by the hoisting drum. The dials of all the indicators are prominently placed in the operating house in order to be well within the view of the hoist attendant.

Lürmann Furnace Hoist.—Another modification of the inclined furnace hoist has been designed by Lürmann, of Osnabrück. In his opinion, it is a defect in the older types that, as the skip is tipped, the coarser material is shot at one side of the hopper, while the finer material will lie in a heap on the other side. Moreover, the throw has the effect of breaking the coke, and thereby wasting it. Reference has already been made to the remedies for this defect. But over and above this objection

to the older type of inclined furnace elevator, Lürmann correctly maintains that with only one hoist for each furnace any breakdown will bring the work of the furnace to a standstill.

Fig. 576. A Typical American Furnace Hoist.

Fig. 576 shows one of a couple of furnaces which have been connected by a gantry or bridge, against the centre of which, and between the furnaces, two inclined hoists are fixed.

The skip, which will take 6 to 20 tons of ore, as it is charged from the pockets, is bodily drawn up on the cradle of the hoist, and as it reaches the top, the rails on

the gantry correspond with the rail portion of the cradle, and the skip is carried by its own weight down a slight incline to the furnace, emptying itself as it passes over the conically shaped mouth.

As the loaded skip automatically runs towards one of the furnaces, it raises a counterweight, which, as soon as the skip is discharged, draws it back to the lifts.

The Lürmann principle has undoubtedly this advantage, that in case of a breakdown of one of the two hoists, the other can be used to serve both furnaces. A second advantage no doubt is this, that the rails on the cradle, when in its lowest position, correspond with the rails which lie parallel to the furnaces, and run right under the store bins from which the skip is to be filled.

Furnace Hoists of the Brown Hoisting Machinery Co.—Fig. 576 shows an American furnace elevator erected by the Brown Hoisting Machinery Co.

This consists of an inclined iron-trussed bridge reaching from the floor of the stock house to the top of the furnace shell, and from thence over the top opening of the furnace. On this inclined bridge are laid the rails, on which travels a skip or car containing a charge of from 1 to 3 tons, as may be desired.

The track is so arranged at the top that the skip automatically discharges itself, as already described. The hoisting is effected by a two-cylinder engine, with a friction clutch drum, installed at the foot of the incline, while the skip is lowered to the bottom for refilling by means of a powerful foot brake, without reversing the engine.

Fig. 577 shows a portion of the Carrie furnaces of the Carnegie Steel Co., with the conveying plant serving them. It is the work of the Brown Hoisting Machinery Co. The coal-tip on the right deals with the material received by rail. The material discharged from the rail trucks into the pocket is withdrawn into buckets holding about 10 tons each. These buckets are placed on electric cars, each of which can hold four. The buckets are then picked up by the Brown travelling crane, as shown in the illustration, and the ore is emptied on to the stock piles or into the pockets in front of the furnace. From these the ore is drawn out through suitable openings into electric travelling trolleys, one of which is shown in Fig. 678, Chapter XXXI. These are so made as to hold one charge of the elevator skip which takes the material to the top of the furnaces. The trucks are equipped with weighing machines, so that the exact quantity required can be taken at each trip.

THE HANDLING OF ORE FROM SHIP OR STOCK PILES TO FURNACE HOISTS

The Hoover & Mason Ore-Handling Plant.—This very interesting plant has been installed at the South Works of the Illinois Steel Co., U.S.A., and the makers, Messrs Hoover & Mason, Chicago, claim that it has solved problems which have confronted engineers for years past. They point not only to the quick discharge of the ore from the hold of a vessel, but also to its stocking in the blast-furnace yard, where it is always readily accessible; to its economical handling by means of the bin system, in connection with coke and limestone, and to its continuous delivery at the top of the blast-furnace.

This plant has now been in operation for a considerable number of years, and comprises a complete equipment for receiving the ore by water, unloading it from the vessels, stocking, and finally delivering it to the furnaces.

A feature of this plant is the utilisation to the fullest extent of the peculiar position

of the furnaces, which are directly served by lake steamers, a considerable portion of the ore coming direct from the mine to the furnace.

Fig. 577. Portion of the Furnaces of the Carnegie Steel and Iron Co.

The general outline of the scheme is shown in the plan, Fig. 584; and to a somewhat larger scale in the elevation, Fig. 578.

A long line of uploaders, fifteen in number, is placed at the dock front, thus making it possible to simultaneously attack every hatch in a large lake vessel. Each uploader manipulates a 5-ton grab, operated by one man, and makes sixty trips per hour, giving a gross capacity to the first half of the vessel of 3,000 tons per hour.

The unloaders deliver the ore into trucks for carriage to distant points, or into the adjacent concrete trough-shaped ore pocket in their rear. In this manner, practically the first half of the cargo is discharged in the first hour.

The residue has to be brought to a point beneath the hatchways before it can be taken out by the grabs. This is effected by a series of scrapers, one at each hatch, operated by an engine installed on the unloader on the shore, which controls the scrapers in the hold, by light ropes.

The diagram, Fig. 579, represents a part section through the vessel; whilst Fig. 580 is a part plan of the vessel showing method of mechanical trimming.

The scraper has a resemblance to a giant hoe, and weighs more than a ton. Its form is shown in Fig. 581. The ore is handled by alternately moving this scraper backwards and forwards, the point to which it returns empty being regulated by changing the position of the sheaves, as shown in the plan view of the vessel, Fig. 580. Thus the entire cargo can be unloaded without hand labour.¹ The discharge of the cargo, with the necessary clean up to get the vessel ready for another load, has been accomplished in four hours.

The unloaders receive steam from the blast-furnace boilers through a line laid in a conduit, and along the dock front in a tunnel within the concrete trough construction, each unloader being connected with the main by a flexible pipe.

As regards soft or hard ores, the capacity differs but little. The work of stocking the ore or transferring it direct from the vessel to a trough 600 ft. long immediately in the rear of the unloaders, or from the stock pile to the furnace pockets, is accomplished by means of two high-level cranes, each 520 ft. long, which are traversed by electric trolleys, each of which contains mechanism for the control of 10-ton grabs, and commands all the various materials for the furnace, including a reserve stock of limestone and coke. Each crane is controlled by a single operator, who can at will pick up 10 to 15 tons, and transport it to the furnace hoist, the hoisting speed being 100 ft. per minute, while the conveying speed of the heavy trolley is 1,000 ft. a minute.

Street car electro-motors, with brakes and controllers, are used throughout the installation, two

¹ The Brown Hoisting Machinery Co. have recently introduced a power scraper shovel for this same purpose of trimming in the holds of vessels, to facilitate the working of grabs in a very effectual manner.

125 H.P. Westinghouse railway motors accomplishing the digging and hoisting, whilst two of 35 H.P. give the transverse motion to each trolley.

The current is transmitted to the trolley by conductor rails, one being placed on each side of the bridge, about 23 ft. apart. Two cast-iron shoe collectors are provided to each rail, in order to prevent sparking under maximum demands of 900 amperes.

At each end of the bridge provision is made against a runaway, in the shape of

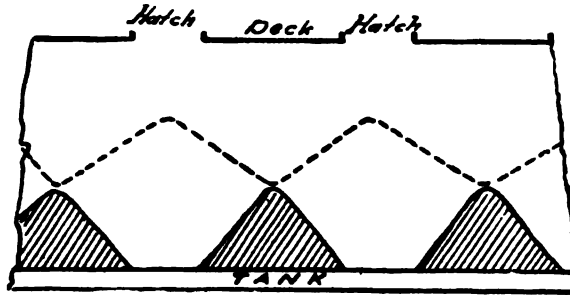


Fig. 579. Part Section through Vessel.

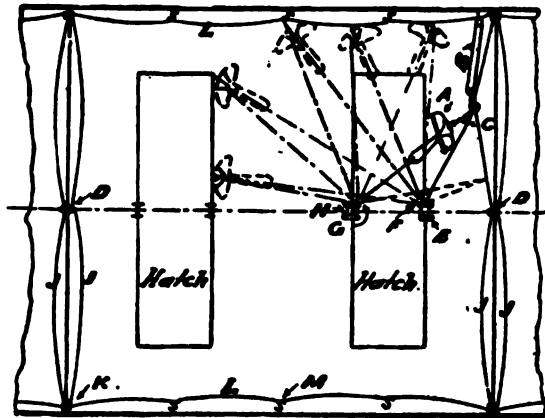


Fig. 580. Part Plan of Vessel showing Method of Mechanical Trimming.

- | | |
|--------------------------------|---|
| A. Scraper. | G. Sleeve Nut. |
| B. Pull-back Tackle. | H. Stanchion. |
| C. Bulkhead. | J. Bulkhead Pennant. |
| D. Middle Bulkhead Hooks. | K. Double Eyebolt for Bulkhead. |
| E. Stanchion Bulkhead Bracket. | L. Side Pennant, $\frac{3}{4}$ -in. Rope. |
| F. Stanchion Block. | M. Hold-back Hooks. |

twelve Westinghouse friction drawheads, which act as buffers. These have been found very efficient in checking heavy trolleys. The bridges rest upon standard gauge tracks, placed upon concrete walls 33 ft. high. The transporter itself has a novel function in respect to its movement, having the capacity to assume positions not necessarily at right angles to the axis of the supporting tracks. One end of the bridge may thus be kept stationary while the other end is moved a distance of 300 ft., thereby giving an elasticity to the work, which is highly desirable.

In this way all the operations at the furnace side of the ore yard may be effected

without moving the transporter upon its track. The total weight of each truss, including the supporting trolleys, is about 450 tons. The supports for each truss over the walls are as follows: On each trolley is a turntable, similar to a swing-bridge turntable, but the trusses also rest upon a nest of parallel rollers on the south walls, which permit of a variation in span length due to the obliquity resulting from the angular movement of the bridges. During the time the crane is traversing the length of the ore yard the work of excavating and delivering is not interfered with, both operations proceeding simultaneously.

The furnace pockets, shown in Figs. 582 and 583, have a capacity of 3,000 tons of ore, 1,000 tons of coke, and 500 tons of limestone. These are double pockets, the south tier being almost entirely used for the storage of coke and stone, and the north tier for ore. A large portion of the ore is conveyed direct to the pockets by the crane, but as the ore

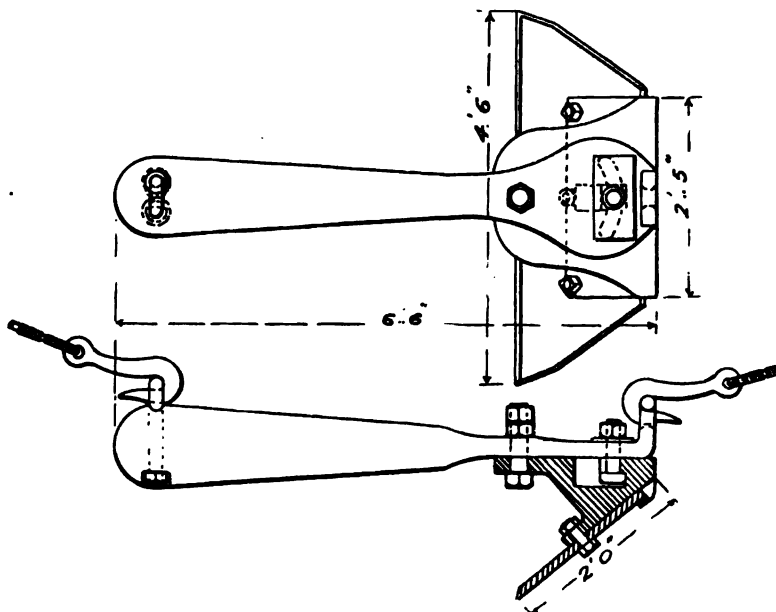


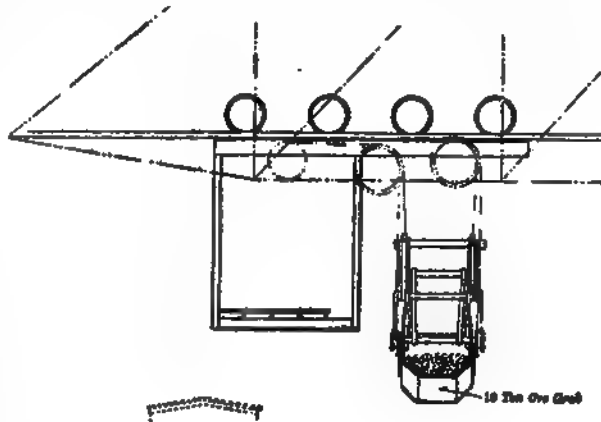
Fig. 581. Plan and Section of Scraper used in connection with Hoover & Mason's Ore-Handling Plant.

yard could not be placed symmetrically to the furnaces, a transfer car became necessary. The body of this is 26 ft. long by 18 ft. wide. This bridge is of such large dimensions that the bridge operator can forthwith deliver his load of 10 tons taken from the trough or from the stock heap.

The grab, when open, commands an area of 19 ft. by 6 ft. The skewing of the ore bridge, which brings the grab in position across the line of the axis of the pockets, necessarily affects the size of the car.

The dumping or discharging is at the side, the opening of the doors being by gravity, while they are closed by a small motor. To avoid danger of collision with scattered lumps of ore, the operator's car is placed upon a sort of outrigger. The size of the car permits of the ore being delivered to either side of the pockets. The car body is of great weight, and thus the shock of receiving a mass of 15 tons is minimised. It is electrically operated by one man who travels with it, controlling it by ordinary

tram-car devices. The ore pockets are constructed of steel throughout, and designed to prevent the formation of arches in the ore mass and consequent interruption in the feed. The sectional view, Figs. 582 and 583, shows how this is accomplished by louvres. These louvres also afford access to the pockets in the case of a few very sticky ores, which, despite the louvres, have a tendency to choke. The withdrawing of ore from the pockets is effected by a rotating cylinder 5 ft. in diameter. The aperture for the exit of the ore is in all cases equal to the width of the pocket, so that the ends of the pocket are vertical. When it is desired to withdraw ore, these rollers are set in motion, forming a feeding device which carries the ore out of the pocket, and to a considerable extent loosens up the mass within the pocket. These rollers are actuated by a motor-driven continuous running shaft, which can be geared to them by a friction clutch.



The rollers on the coke side are perforated, and efficiently act as screens in separating the dust from the coke (see Fig. 583).

A hot-air chamber is placed under the ore bins in order to prevent their contents from freezing in cold weather.

One weighing truck only is needed for each furnace. Each weighing truck has two compartments, each holding a skipful (see Fig. 583). All material delivered to the furnace is weighed before entering the skip. The weighing truck is driven by electricity. The weight of each increment is recorded upon a strip of paper by the balancing of the beam, and is thus placed beyond the reach of any tampering, an unimpeachable record being kept of the total weight of material fed into the furnace. In the course of a year one man has kept a large furnace full without difficulty. The coke is distributed along a considerable length, and not, as is often the case, into two large ore bins, delivering directly into the skip. The advantages of this plan are, firstly, that it enables

Figs. 582 and 583. Showing Hoover & Mason's Ore and Coke Pockets and Scale Car.

a large number of coke cars to be run over the pockets and unloaded simultaneously; secondly, it obviates the drawback of these large pockets, as the proportion of dust entering the furnace at one time is minimised; thirdly, it is found that by putting the coke through a weighing truck the dust therefrom prevents the ore from sticking to the truck, and thus quickens the discharge. The fact that one man can maintain the furnace shows sensitive and rapidly delivering pockets. The operator need not quit his station for any purpose. He can control either truck or pockets from one position, pendant cords somewhat like a bell-rope being conveniently placed, and by simply pulling the rope he can, in a few seconds, load his car. The load on the car is indicated

Fig. 584. Plan of Hoover & Mason's Ore-Handling Plant.

by a hand on the dial. Buttons of different colours are placed on this dial, each button corresponding to a load of ore, coke, or limestone. The operator pulls the cord until the index finger travels to its proper position; he then releases it, and the charging

In both the 5 and 10 ton grabs the path of the cutting edge through the material and the inclination of the tray follow certain lines which it is claimed have been found most efficient for digging ore. The construction of these grabs permits of the path being altered to suit any given material. It may be of such a character as to make an even cut of 6 or 8 in. below the surface over the area contained in the closing stroke, or a cut to any other depth (within certain limits) that the nature of the material may

call for. The ore trough is essential for two considerations: firstly, in the event of its being desired to speedily discharge a vessel, as the shorter the distance the ore is moved the more quickly this will be accomplished; secondly, the stock pile should at all times be accessible to the transporter which takes the ore to feed the furnaces. All ore taken from the vessel's hold, except such as is immediately dropped into trucks for carriage to more distant points, is unloaded into the trough at the rear of the unloaders, and thence is distributed by the 10-ton grabs into the stock yard, or directly into the pockets situated near the furnace. Thus the fifteen 5-ton grabs can be constantly at work removing the ore from vessels, whilst the 10-ton grabs can either be feeding the furnaces from the stock pile, or removing the ore from the trough to the stock piles.¹

¹ The Author is indebted to the *Iron Trade Review*, of Cleveland, Ohio, and to the *Iron Age*, of New York, for the above description.

CHAPTER XXIX

THE MECHANICAL HANDLING OF COKE FROM COKE OVENS

THE industrial history of the past fifty-five years may be called absolutely distinct from that of any preceding period, and we see a complete revolution in all that part of our social life which is effected by industrial and mechanical appliances. This is specially so in regard to labour saving devices; it is a remarkable fact, however, that those arts whose functions it is to make the daily life of the toiler more endurable, were the last to be touched and invigorated by the talisman of the twentieth century inventive activity.

The toiler at the coke oven is, perhaps, one of those whose arduous labours are made more unendurable by the intense heat, the steam of the quenching, and the sometimes stifling sulphur fumes, in which he has to perform his duty, and yet there are only comparatively few coking establishments which have taken any steps to ameliorate the lot of these workers, and to benefit commercially by the same means.

Coke ovens, whether antiquated or modern, whether charged and drawn by hand or by machinery, give employment to great numbers of men who perform the operations of quenching, breaking up, spreading, and finally loading the coke, all of which take considerable time, and are therefore expensive.

The coke ovens themselves, and their more or less mechanical appliances, do not here concern us; may it suffice to say that a great many modern installations in this country and abroad are now met with, which are fitted with the most elaborate up-to-date charging and discharging devices, but yet the means of handling the coke after it has left the ovens have been sorely neglected, probably on account of the great difficulty which this problem presents, and though this chapter is devoted to this particular subject, it is a question whether any of the numerous improvements given in it may be looked upon as the final solution of the problem.

Mr A. Thau, who was closely connected with the subject in this country as well as on the Continent, has written an able paper on this important question, which has appeared in "Glückauf," and the author is indebted to him for the facts which form the basis of the following.

It is difficult to separate the mechanical handling of coke as it leaves the ovens from the quenching process, and both are, therefore, taken together for this reason as well as for that of completeness in investigating an important process of a vast industry.

The old method of dealing with coke from the ovens, and one which is still in vogue in probably the majority of coke oven installations, is very simple, as it is altogether devoid of mechanical contrivances. In front of the ovens there is a wide hearth or platform with a slight inclination away from them. The hearth is covered with cast-iron plates, and on the side opposite the ovens there are one or more lines of rails for the trucks into which the coke is to be finally loaded. The hearth, as a rule, is at its lower side on a level sufficiently high for the coke to be dropped by gravity into the trucks. The slight gradient of the hearth is for the purpose of allowing the surplus quenching water to run away, and in order to prevent this water from running into the railway trucks there

is a gutter with drainage about a yard away from its lower edge and running the whole length of the hearth.

The *modus operandi* is as follows: As soon as the coke has been pressed out of the oven it is played upon with a hose, and quenched externally; it is then broken up and raked apart with hooks and rods, and is finally quenched throughout. As soon as the surplus water has evaporated and the coke is sufficiently cooled it is forked into barrows and transferred into the railway trucks on the adjoining track.

This is all very simple, but also very cumbersome, and attempts have not been wanting to replace this method by mechanical devices; certain conditions, however, have to be observed, whether the treatment is manual or mechanical, and it is therefore well to make this quite clear before going closely into the mechanical means employed.

The coke should be drenched immediately it leaves the oven, and, if possible, before it has had time to come into much contact with the air, as otherwise it will become discoloured and of less value. Then it is of great importance that the quenching and cooling should be uniform throughout the whole mass, as otherwise pieces might reignite in the railway trucks and damage them; it is therefore necessary to spread the coke well, let it cool for at least a quarter of an hour, and thus give time for the heat of the material to evaporate the surplus moisture and become uniformly cool. The coke as loaded should not contain more than 4 to 5 per cent. of moisture. Large coke alone is loaded into the railway trucks; the breeze and imperfectly coked portions, such as occur in ovens of old pattern, and round the doors of ovens with horizontal flues, should be eliminated.

The object of the systems now to be described is to substitute mechanical means for one or more of the operations hitherto performed by hand, and thereby to reduce the cost of production as well as to make the work of those employed less onerous.

It has already been mentioned that railway trucks to be loaded should be so situated, relatively to the platform, as to prevent waste through breakage, and yet to enable the operation to be carried on conveniently, say 18 in. from the platform to the top of the trucks; if it is more the fall of the coke into the trucks is too great, and likely to break the coke and thus lessen its value. Such a position between the truck and the hearth is undoubtedly the best, but in older installations it is frequently found that the hearth is much lower than that, and since the hearth, and with it the ovens, cannot be raised without rebuilding the whole installation, matters can sometimes be improved by lowering the siding for the trucks sufficiently to bring them below the hearth, but where this is impossible there is no other alternative but to lift the coke from the hearth into the trucks. Under such circumstances the best plan is to fill the coke into iron crates or into skips, preferably with bottom discharge, and raise them by a crane over and into the railway trucks. Grabs are unsuitable on account of the brittle nature of the coke. In order to save shunting, loading cranes in large installations are made with a sufficient reach of jib to load two or three lines of trucks.

Where coke ovens serve blast-furnaces direct, the coke is generally forked into tip-trucks, which convey it to the furnace, or the skips may be placed by the crane on platform wagons, as is the custom at the Port Clarence Ironworks at Middlesbrough. Here large electrically driven platform trucks are used to carry the skips to the furnaces, some distance off. In this particular case the height of the platform truck is such as to be on a level with the hearth, but this arrangement is here mentioned as it might equally well be applied in cases where the height of the platform truck is lower.

Having now dealt with these expedients under existing circumstances, we will pay attention to mechanical installations for more modern cokeries, where the hearth is at a higher level than the trucks.

One of the first attempts at mechanical loading was the installation of a portable band conveyor, mounted on wheels, and running on three rails right across the hearth, as shown in Fig. 585, constructed by Coulson & Co., Spennymoor. The conveying band *a* reaches close to the ovens *b*, and can traverse the whole of the hearth in front of the battery of ovens. The delivery end reaches to the middle of the trucks. The conveyor is fitted with electric motor, and the current is taken from an overhead wire on lamp standards by a trolley, so that the motive power is available in whatever position the

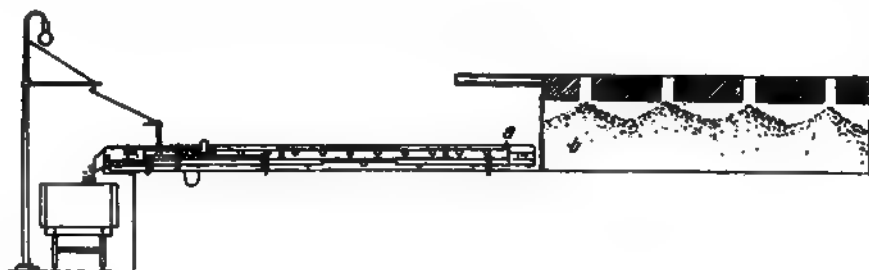


Fig. 585. Portable Coke Conveyor by Coulson & Co., Spennymoor.

conveyor may stand. The conveyor is driven close to the quenched and cooled coke to be loaded, set in motion, and the coke is then put on with the usual large forks which leave the breeze on the hearth. The utility of these and similar transporters is somewhat marred, as the quenched coke on the hearth restricts the movements of the conveyor to narrow limits, and therefore makes it impossible to load the coke in the rotation in which it is pressed; it has rather to be taken from the spot where the conveyor may happen to stand. There is no apparent mechanical objection to erect such bands on carriages

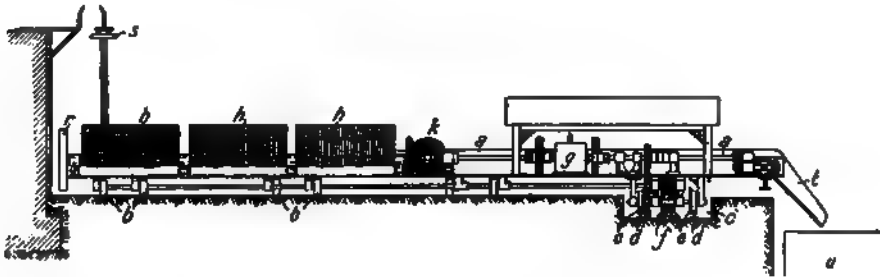
Fig. 586. The Baglin Coke Loader.

sufficiently high to clear the coke on the hearth, but then the rails would have to be cleared for its passage. The latter difficulty has been overcome by the Baglin machine (Fig. 586), which has been built since 1908. It is movable on a carriage *a* and a pair of rails at the lower end of the hearth, so that the apparatus can be moved freely, and the coke may be loaded in the rotation in which it is pressed. The conveyor *b* covers the major portion of the hearth and reaches to the centre of the truck; the shorter section is furnished with a weight to balance the longer end. The carriage *a* has a covered-in driver's stand with motor and countershaft, and is self-propelling. Although the coke has to be lifted by the men with the forks a little higher than in the scheme previously

described, it has the advantage that men can load it from both sides, and, furthermore, when one truck is full, the band may be stopped with the full load on it, and driven to the next truck to be filled.

There is, however, the great disadvantage common to both systems, that a large gang of men have to be employed to load the coke by hand, and whether they load it on to a band conveyor or into a skip or crate, to be subsequently moved by a crane, is really of little consequence, so the apparent advantage of the conveyor over the crane and skips is more or less illusory, and the working expenses will probably be much the same.

Mechanical appliances have been introduced of late years for coke ovens, fitted with level hearths, for lifting the coke on to the conveyors, and thus dispensing with a gang of hand labourers. Figs. 587, 588, and 589 show a conveyor so fitted with lifting appliances ;



Figs. 587 and 588.—Kickert's Method of Handling Coke.

a. The conveyor. *b.* Wheels running on the hearth without rails. *c.* Recess in hearth. *d.* Rails running the length of the hearth. *e.* Flanged wheels which determine the path of the machine. *f.* Toothed rack running the length of the hearth, by means of which and a wheel coupled to the motor the machine can traverse the length of the hearth. *g.* Motor, coupled at one end to the travelling gear, and to the conveyor and the coke-lifting apparatus. *h.* Coke-lifting apparatus (see Fig. 589). *i.* Spindle. *k.* Gearing of countershaft. *l.* Levers carrying the lifters. *m.* Lifters. *n* and *o.* Forming a revolving frame. *p.* Strip which fills the space between lifters and conveyor. *q.* Guide for coke from lifters. *r.* Flywheel. *s.* Live rail. *t.* Shoot. *u.* Truck.

it is that of Kickert, at Wattenscheid, Germany. Similar appliances dealt with previously, render a detailed description unnecessary, and the explanation of the letters of reference will be sufficient to make the drawing intelligible.

The lifters *m* are so supported and guided that at their lowest position they come close to the hearth to pick up the coke, whilst in ascending they move inward in order to clear the rail *o*.

When coke, sufficiently cooled, is ready for loading, the machine is driven up to the coke, and the three sets of lifters, the teeth of which are about as far apart as the prongs

of a coke fork, lift the coke on to the conveyor whilst the machine slowly advances (see Fig. 589).

A well-designed form of conveyor for coke ovens is the work of Mr Joseph Müller, of the Matthias Colliery, at Essen, in Germany. This appliance is intended to take the coke as it comes from the ovens in a red-hot state and at once quench it in water, to allow it to dry and be discharged on a sieve or grate, and finally to load it into wagons or boats in one continuous and automatic operation.

A diagrammatic view of the apparatus by which this is accomplished is shown in Fig. 590. In front of the outlets of the coke ovens there is a tank B, which is kept full of water. The right end of the tank has a sloping side. In this tank is placed the carrier and conveyor, which consists of a strong frame on

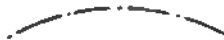


Fig. 590. Müller Hot Coke Conveyor.

Fig. 589. Cross Section through one of Kickert's Lifters.

wheels which runs on three transverse rails, allowing the whole apparatus to be moved crosswise in the tank. Strong side beams of plates and bars form the frame of the carrier. Cross-bars and stays serve to strengthen it laterally. That part of the carrier frame near the oven is built horizontally, and is completely immersed in the water. The other part rises gradually, and at its further end is entirely out of the water and so high that there is sufficient room below it for a sieve or grating at s, which may be built in one with the carrier, or may form a separate part of the apparatus. The sieve or grating may be made with movable bars, or the latter may be fixtures. When arranged separately from the transporter frame, the sieve may extend for the whole length of the hearth.

The carrier band consists of two chains, one at the right and the other at the left edge. They are connected laterally by means of bolts, which bolts form at the same

time the axles for the carrier wheels upon which the chains are carried forward. Plates riveted or bolted to the chains, and each reaching from one side to the other, of exactly the width of the pitch of the chain links, form together a continuous platform.

The coke coming from the furnace in a hot glowing state is pushed directly upon the carrier chain into the tank, where it is quenched and slowly carried forward. At the further end it is raised out of the water, and upon the rising part of the carrier chain the water can run off and the coke is dried, the latent heat contained in it quickening the process, so that it arrives almost dry at the end, where it is thrown automatically upon the grating, and after the breeze has been eliminated by the latter the coke is discharged into wagons.

The transporting band or table moves between two inclined side shields *v*, which are so fixed to the carrier frame that the plates pass below the lower edge of the shields, thus preventing the escape of any coke. The rails or guides for the chain wheels are formed by the channel irons which are parts of the carrier frame. The upper horizontal flange carries the upper chain, while the lower horizontal flange carries the lower or returning chain.

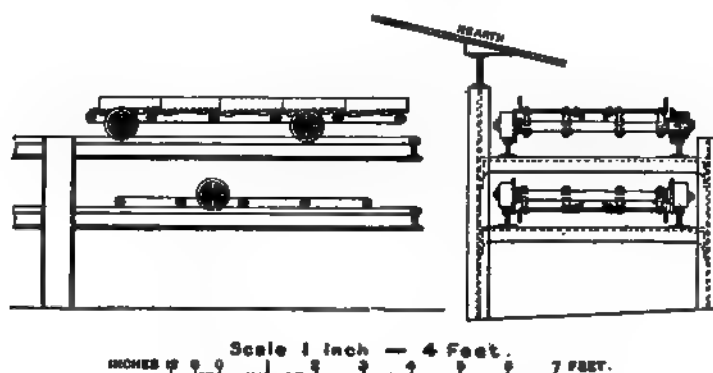
When a coke oven has been emptied, and the coke from it has been quenched, conveyed away, and loaded, the whole apparatus is shifted sideways in front of another oven ready for discharge.

In the installation at the ironworks at Dumbrick Pavell the hot coke conveyors are erected in front of and parallel with the hearth. The coke is partly quenched on the inclined hearth and then raked into the conveyors which are 3 ft. wide, and 392 ft. 6 in. long, from centre to centre of terminals. The trays are made of $\frac{1}{4}$ -in. mild steel plates with edges turned up to form sides. Each tray is riveted to a manganese cast steel driving link 15 in. pitch, and the links are coupled together with pins of $1\frac{1}{4}$ in. diameter. To every third tray is bolted an axle with two wheels, each of 6 in. diameter. The axles are made of mild steel, the ends of which are lapped with blister steel and welded, and are machined, bored, and hardened. The



Fig. 501. Elevation of Hot Coke Conveyor at Dumbrick Pavell.

wheels are of cast iron bored out to fit the ends of the axles, and kept in position with collars on the inside, and nut and washer on the outside. The hollow ends of the axles are lubricated by viscous lubricant, a brass plug being screwed in the end. Lubrication is effected by a boy standing at the side of the conveyor and giving each brass plug a turn with a spanner, which causes the lubricant to flow to the outside of the axle. The wheels run on rails supported on girders. The driving drums are of cast



Figs. 592 and 593. Coke Oven Conveyor at Dumbrick Pavell.

steel and hexagonal, with renewable teeth. The conveyor has a speed of 30 ft. per minute, but only works intermittently. At present it conveys 150 tons of coke per twenty-four hours.

In Fig. 591 is shown an elevation of the installation, while Figs. 592 and 593 give an elevation and a cross section showing the conveyor to a larger scale.

It is a fact that people sometimes go out of their way to introduce elaborate mechanical devices, when by a judicious general arrangement much might be done by gravity and without mechanical handling. A case of the latter category may be cited in connection with the coke ovens of the Mitchell Main Colliery, Barnsley. Here the hearth is erected on parallel rows of cast-iron stanchions, not as usual on walls and masonry arches, so that there is room under the ramp for the sidings and the coke trucks; in this hearth there are a series of openings or traps of 18 to 20 in. square, to which angle-iron coamings are riveted, and they are fitted with lids. When the coke

Fig. 594. Coke Loading Device of Grégoire.

has been quenched, spread, and cooled on the ramp, it is shovelled down these holes into the trucks; the angle-iron coaming to the openings is there to prevent the quenching water from running into the trucks.

A different principle is that of Grégoire, Seraing, in Belgium, shown in Figs. 594 and 595. In this system the coke is moved after cooling on the ramp by a mechanically driven plough running on two lines of rails parallel to the battery, which pushes the coke into the trucks. The plough is driven, as shown in Fig. 595, by a motor and the transmission *a, b, c, d* and the chains *e* and *f*, which gear on to the back axle. The carriage

forms a triangular plough, which runs on three wheels, two behind and one in front; the latter is controlled by steering wheel *g*. The two lines run into one at the extreme end of the hearth, so that by running the plough first on the front rails, disposing of the coke in front, and then on the back rails, the coke is pushed from the back forward, to be finally loaded by a second journey of the plough along the front rails. In order to negotiate

Fig. 595. Section through Grégoire's Coke Loading Device.

these points and rather sharp curves more easily, one of the back wheels is loose on the axle, but can be coupled up by the hand lever *k*. The carriage is protected by iron plates attached to the frame *i*, and the oblique ploughing plate is bent at the bottom similar to a ploughshare, so as to lift the coke, and it reaches to within an inch of the hearth plates. At the base of this triangular carriage is a plate *h*, which can be lifted or lowered by hand lever *l*. The wheels are protected by guards *m*, and, in addition to this, there are sweepers provided to keep the track clear of coke. Along the front edge of the hearth are a series of hopper shoots to correspond with the truck into which the plough pushes the coke, and as this plough does not come close down on the hearth, the breeze is left, and can be collected on the return journey of the plough, by the plate *k*, which can be lowered right down on to the hearth plates. As far as the writer is aware, this machine has not been tried in practice, and there are several obvious objections, one being that conditions as shown in Fig. 594 will probably never obtain, as some of the coke may not be ready in the rotation in which the machine can move it. The description has, however, been given as a link in the chain of possible development on an entirely different principle.

Quenching by mechanical devices is now largely used in modern installations, and they consist generally of a framework constructed of pipes perforated on the side towards the coke; these frames are moved in front of the oven door, thus drenching the coke as it is forced out by the coke pusher.

The oldest form of quenching device, which forms the basis for all further improvements, is shown in Figs. 596 and 597. In an installation of this kind a framework *a* is

Fig. 596. The Oldest Form of Quenching Device for Coke.

erected and fastened to the ovens. This supports a longitudinal girder *b*, on the bottom flange of which moves the trolley *c* that supports the quenching apparatus on a swivel and two chains, in such a manner that it can be easily conveyed to any of the ovens of the battery which may be ready for pressing. The water main *d* has a number of T-pieces with valve and hose connections, so that the main may be connected with the apparatus wherever wanted. The arrangement of the sprinkling pipes is seen from the illustration,

and consists of six or more pairs of pipes according to the height of the ovens, the middle and the top one of a larger diameter; the former because they serve as a connection to the main, and the latter for the sake of strength, and also in order to give a more copious supply of water on top of the coke cake, where it is always more or less divided or open, as this is the best way of getting quenching water to the interior of the coke before breaking it up. When the apparatus is in position and connected to the main the oven door is lifted, and the coke is pushed slowly through the quenching apparatus. It

Fig. 597. Sectional Plan of Quenching Device shown in Fig. 596.

has already been mentioned that the hearth must have a slight fall, away from the ovens. This is particularly necessary when this form of quenching is adopted, as it necessitates the use of a large quantity of water in very close proximity to the ovens, and it is therefore advisable to give a gradient to the hearth of not less than 10 per cent. to prevent the water from entering the ovens.

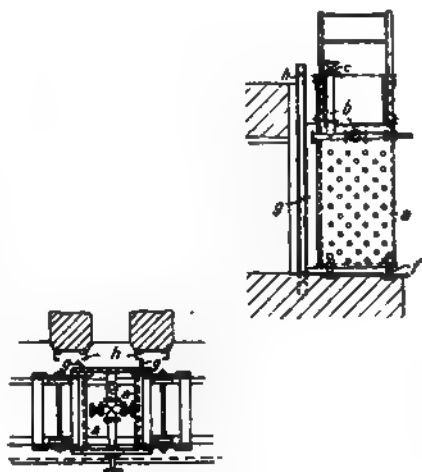
It has been found that if the coke is pressed at a speed of 6 ft. per minute the automatic quenching can be done thoroughly. If the mechanical appliances of the ovens do not permit of so slow a speed, it is advisable to push for a distance equal to the reach of the quenching pipes; then stop and quench for one minute; then push again, and so on. The quenching of the coke in this manner saves very considerably in labour, and the appearance of the coke is excellent. On the other hand, it must be mentioned that the water-quantity used is two to three times as much as in the old-fashioned way, and in consequence of the slow pressing the rod and head are exposed to the temperature of the oven for a considerable time, so that even if they are made of cast steel they will require more frequent renewal. In spite of this, the advantages are of such importance that mechanical quenching processes are largely used, particularly in Great Britain.

The well-known Darby coke quencher is shown in Figs. 598 and 599; its special feature is provision for excluding access of air to the coke. The appliance consists of the main pipe *a*, which branches off into smaller pipes *b*. To exclude the air, plates *c* are employed to close the space between the pipes, and the spray of water passes through a great number of small nozzles which are screwed into the pipe, and extend

Figs. 598 and 599. The Darby Coke Quencher.

through the plates *c*, which latter are held by staples *d*. The whole is suspended from the main water supply pipe by rollers *f* and chains *e*. Pipe *a* has a further extension, and a branch *g* which supplies a copious stream of water against the front of the coke and after this begins to break, to its inner parts.

The coke quencher of the A. G. für Kohlendistillation at Gelsenkirchen (Figs. 600 to 602) differs from the installation last described inasmuch as the nozzles, which are liable to become choked, particularly when dirty water is used, are omitted, and the pipes are replaced by two water jackets, forming water chambers *a*, which form continuations of the oven sides. The water is admitted through the main pipe *b*, which is connected with the flexible supply pipe by means of the sluice valve *c*, and issues through perforations in the inner walls of the chambers. The flow is regulated by taps *d* between the pipe *b* and the chambers. The latter are closed at their lower extremities by plate *e*, which can be removed for cleaning purposes. The apparatus is mounted on an iron frame running on four wheels on channel-iron tracks, which are filled up between the wheels by inverted channel-irons *f*, so as not to impede the pushing operation. Two pivoted vertical strips *g* fit against the oven door frames *h*, and prevent access of air and



Figs. 600, 601, and 602. Coke Quencher of the A. G. für Kohlendistillation at Gelsenkirchen, Germany.

Fig. 603. Hearth with an Incline of 15° to 30°.

waste of coke. The water pressure for these appliances must be at least 75 lb. per square inch, so that the jets are forced out of the perforations with sufficient pressure. This obviously means a larger water consumption.

The handling and quenching methods hitherto described are practically all for

platforms or hearths which are nearly level, and have only sufficient slope to allow the quenching water to run away, and some of the appliances must be looked upon as the best that could be done under existing circumstances, whilst the tendency in new cokeries, both in England and on the Continent, is to place the ramp at an angle of 15° to 30° to the horizontal according to the method of loading which may be chosen. Fig. 603 shows such an arrangement. In front of the oven doors is a nearly level space *a*, about 6 ft. wide,

which rounds off into the slope *b*; the former serves for quenching the coke when done by hand, affords a suitable passage to attend to the ovens, and finally forms practically a continuation of the oven base and a support for the head of the coke-pusher, so that the coke can be ejected to a sufficient distance. If a quenching machine is employed, the rail track is arranged on this upper nearly level platform. The slope terminates in a lower horizontal portion *c*, and at the bottom of the slope is a gutter *d* covered with perforated plate to carry off the superfluous quenching water. The railway track is sunk so that the upper edge of the trucks is either flush with the lower platform, or better, projects somewhat above same, as shown in the illustration; in either case the coke has to be lifted into the trucks by means of forks, which separate the large coke from the small. These sloping platforms are convenient, so far as the handling of the coke is concerned, as the coke falls to pieces as soon as it overhangs the greater slope of the ramp, and thereby saves hand labour; it also, after cooling, slides down with little help, and avoids the use of barrows. Such an installation is, however, more expensive on account of the necessary excavations and the higher elevation of the ovens themselves.

Fig. 604. Peel's Antibreaker.

At the cokery of the Seaton Carew Ironworks, West Hartlepool, the ovens are mounted at a sufficient elevation to allow the sloping platform to deliver direct into the coke bunkers, from which the quenching water is excluded by a rail and gutter at the bottom of the slope; this rail also keeps back the small coke and breeze. The water main and hydrants for the quenching machine are carried on a bridge above the bunkers. The arrangement is convenient, as enabling the coke to be delivered to the bunkers, and again from there to the trucks, with a minimum of hand labour, and without mechanical appliances; but is expensive to construct owing to the height of the substructure of the coke ovens. Mechanical quenchers are nearly always used with such installations, but with these steep ramps there is a tendency for portions of the coke to become detached from the solid mass during the quenching, and roll down the incline and so break up. This is practically prevented by suspending a number of rods about a yard long in front of the quencher so as to give the coke a little support, but "Peel's" Antibreaker, Fig. 604, is more effectual.



Fig. 605. Coke Oven Installation at Rheinhausen.

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Here the front end of the quencher is closed by an iron plate or shield *a*, fitted with strengthening ribs and suspended on a rail track for the purpose. A series of sprinkling pipes is arranged inside the cover plate and supplied with water from a distributing pipe *b* at the top. A triangular recess cut out of the bottom edge of the cover prevents the coke from jamming inside the quencher. An external perforated spraying pipe *c* is arranged on the cover plate, so as to complete the quenching of the issuing coke. This arrangement is simple, cheap, and acts in a highly satisfactory manner.

Mechanical appliances for loading coke after quenching, and in connection with steep ramps, are in use in a great many cokeries now. Fig. 605 shows such a scheme as used at the coking plant of the Friedrich-Alfredhütte, Rheinhausen. The shoots are swivelled and provided with balance weights, and deliver the coke into skips running on overhead rail tracks, on which they are conveyed to the furnaces. Unless forks are used

Fig. 606. Showing Method of Feeding Coke on to Tray Conveyor.

for moving the coke down to the trucks, the small coke and breeze cannot be separated. Otherwise, the illustration explains itself.

By far the most popular method of conveying the coke is a continuous tray conveyor which runs the whole length of the hearth, and which frequently ascends at the delivery terminal and deposits its load into a sifting and classifying plant prior to its further disposal. With this system, largely used in British cokeries, the lower end of the ramp terminates in a perforated plate reaching as far as the edge of the conveyor and draining away the surplus water. To prevent the coke from falling down on to the conveyor before it has sufficiently cooled, a number of swinging loading flaps are arranged at the bottom of the ramp. In small batteries, in which only one charge is loaded at a time, these numerous flaps may be replaced by one portable flap or door mounted on a four-wheeled truck running on rails parallel and on a level with the conveyor. Fig. 606 shows such an appliance of Koppers. This truck, which is moved by hand, carries four flaps, which are brought into the desired position by means of a toothed quadrant *a* engaging with a pinion *b* operated by a hand wheel on a vertical shaft *c* through worm gearing. When the flaps are set on the slant, as in the illustration, they hold back the coke, but when vertical they allow it to fall on to the

conveyor to be removed. With this system the ramp is at an incline of from 30° to 40° , which is sufficient for the coke to slide down; with a lesser incline the flaps are not necessary, and the coke is then raked down. One of these appliances is in use at the Manvers Main Colliery.

A similar plant is that of the Soc. Ilva, at Bagnoli, near Naples; it was built by F. Méguin & Co., in Dillingen. In this the conveyor consists of short links and $\frac{5}{8}$ -in. plates, with angle-iron sides forming a continuous trough; each second link is provided with a spindle and a pair of running wheels. The links and bolts are of manganese steel, whilst the rollers are of chilled iron; they are also self-lubricating

Fig. 607. Coke Conveyor of the Soc. Ilva, at Bagnoli, near Naples.

with a viscous grease, so as to exclude dust. This conveyor is 328 ft. from centre to centre of terminals, is about 3 ft. wide, and handles the coke from two batteries of sixty ovens each, being placed centrally between the two hearths (see Fig. 607). The driving power is furnished by a 12 H.P. electro-motor, which is exceedingly moderate for so large an installation, especially as the delivery end raises the coke to a sufficient height to deliver into a screen, from which the fine coke falls into a bunker, whilst the coarse is conveyed by a swinging shoot into mono-rail skips, which are conveyed by the telpher system to the sloping hoist of the blast-furnace.

The quenching of the coke is effected by means of flexible hose from hydrants on gangway *a*, situated above the conveyor at suitable intervals. The lower end of each ramp *b* is closed by flaps *c* suspended from the gangway, and operated by a bell-

crank *d*, screw spindles *e*, and hand wheel *f*. This device admits the regulation of the supply of coke to the conveyor and protects the coke from breakage. This plant has been successfully in operation for some years.

The system of handling coke by tray conveyors has undoubted advantages, and the reason why they do not receive universal adoption is the wear and tear caused by the cutting nature of the coke inherent to all chain conveyors when handling such material.

A breakdown of the conveyor means practically the suspension of the workings, unless spare parts are kept and repairs can be quickly undertaken. To make this type of conveyor more immune from breakdowns by dispensing with the numerous joints, in the presence of which lies the greatest source of trouble, Wangeman, of Berlin, has introduced a conveyor which resembles in principle the well-known band conveyor running over terminal drums and idlers *b* at frequent intervals (Fig. 608).

The band proper consists of a number of parallel wire cables *c*, each with a core of longitudinal non-conducting material, such as asbestos; these cables are connected by stout lateral wires into a band of great substance and resistance. The coke is allowed to slide down the plates *a*, so as to lie in the central part of the band, and thus protect the idlers with their bearings from dust.

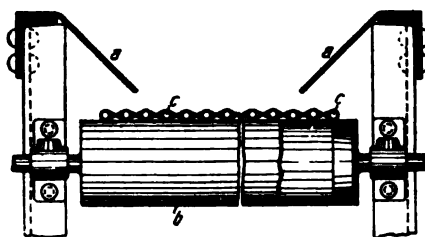


Fig. 608. Jointless Band Conveyor Introduced by Wangeman, of Berlin.

As an example of equipment for horizontal coke platforms, the Burnett quenching and loading device may be mentioned (Fig. 609). It consists of a quencher *a* closed at the top and ends, and extending the full width of the hearth. It is made of deeply corrugated boiler plate, the corrugations being horizontal, and, like the Darby quencher, provided with a system of outside pipes spraying water over the coke block through nozzles pointing inwards, which are protected from frictional contact with the coke by the corrugations. The quencher has no bottom plate, but is closed at the outer end

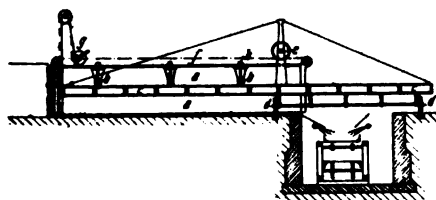


Fig. 609. The Burnett Quenching and Loading Device.

by a plate, and at the inner end by a slide. The steam liberated in quenching escapes through holes in the top. It is supported on rollers *b*, and lateral girders *c*, at a height of about half an inch above the hearth, and can be run along the battery of ovens on wheels *d*. The quencher is moved to and from the ovens by means of the drum *e* and the wire rope *f*. Under the carriage is a sunk conveyor to transport the coke to the screen.

Winch *g* is for the purpose of raising the oven door after the quencher has been placed in position. The charge is now pressed into the quencher, which is moved a little to one side so that the doors of both the oven and quencher may be closed, when the coke block is quenched in its enclosure. As soon as steam ceases to rise from the above-mentioned openings, the quenching process is complete. To enable screened coke to be loaded direct, independently of a conveyor, the apparatus may be modified so that sufficient space is left between it and the railway track for a screen, adapted to be raised and lowered by ropes running over pulleys, and to enable the rail track to be laid on a higher level. The coke can

be delivered into a bunker and raised by a bucket elevator to the screen. The Burnett machine is simple, but requires plenty of room, which is not always available in old cokeries.

The Méguin loader for coke (Fig. 610) was built for a Belgian cokery, and consists

Fig. 610. The Méguin Loader.

of a portable contrivance having a screen connected with an inclined plate conveyor *a*, with angle-iron sides. It delivers the coke to a bar screen *b*, provided with a balanced swing extension *c*, enabling the coke to be loaded into any desired truck. The screenings fall into a bunker *d* with a discharge slide *e*; the conveyor is driven by a belt from shaft *f*, and the travelling motion of the whole carriage is transmitted by chain *g*.

Fig. 611. Portable Loading Device of Allport.

As the illustration shows, the Méguin loader runs on a rail track parallel with the ramp, and between it and the siding for the coke trucks; the ramp is sufficiently steep for the coke to slide down readily. There is a tendency to make the hearth or ramp still shorter and steeper in order to use it simply as a means of conveying by gravity, instead of its original purpose, *i.e.*, for cooling, and we shall see that in some instances

the hearth has been dispensed with altogether. Whether this curtailing or omission is altogether a wise plan cannot be determined until installations on such lines have demonstrated their practical advantages by the test of time.

The Allport loader (Fig. 611) belongs to the category of installations with short ramps. Here the coke is mechanically quenched, and then slides over a bar screen (the slack falling into a truck) on to a wide band conveyor mounted on a carriage which can be moved into the loading position, and there fill the trucks.

The machine consists of a frame *a*, with its bearings *b* and axles *c*, which is raised on rails *d*; the conveyor has hexagonal terminals *f* and *f*₁, with their spindles *e* and *e*₁; the band is of wire construction, and can therefore be used to make a further classification of the coke, by adjusting the mesh so as to allow a certain portion to fall through into truck *h*, whilst the large coke is delivered into truck *i*. These conveyors are preferably made in pairs when the space between them is covered by plate *k*.

The machine is driven by a wire rope running parallel with the ramp, and engaging the wheels *l* and *m*, which in their turn are connected by worm and worm wheel to the conveyor, and also to the gearing for the movements of the carriage; these movements are controlled by levers *n* and *o*.

The first installation which was erected at the Wharnccliffe Woodmoor Colliery, near Barnsley, was unfortunately not a success, as the coke was delivered into the trucks so hot as to set them on fire. Several modifications of this system have been made by the inventor and others, but no thoroughly satisfactory results have been obtained. The best modification is a more substantial conveyor on which the coke is re-quenched and allowed to cool before it is set in motion to fill the trucks.

The form of loading appliance mostly used in English cokeries for very short slopes is that at the New Brancepeth Colliery (see Fig. 612), an iron receptacle about 30 ft. long, and running on a track parallel with the coke ovens. This receptacle slopes at an angle of about 40°, and forms a continuation of the hearth, its upper edge being flush with it. The sides are of iron plate, and the lower end of the receptacle is closed by two balanced lattice doors operated by worm gearing. Ropes attached to either end of the receptacle are wound on drums which can be operated alternately by motors, in order to move the machine to and fro along the battery. Where the coke is to be loaded at once, the receptacle is run up an incline to a screen over which it is emptied direct into the railway trucks. The bar screens are arranged to have the same slope as the receptacle, so that the coke slides down at a uniform speed. These screens are generally 30 ft. wide, the same as the receptacle, but in large plants the screen may be twice as wide as the receptacle or conveyor truck, so that each load may rest a while for further cooling. Where space does not permit the use of an inclined track, as at South Brancepeth, a hoist is used.

Fig. 612. Cooling and Loading Receptacle at the New Brancepeth Colliery.

A similar installation to that of the New Brancepeth Colliery, but on a more extensive scale, is now in use at the cokery of the Woodward Iron Co., Woodward, U.S.A. Here the receptacle is much larger and of a slightly different form, whilst the coke is quenched by pipes with flattened nozzles placed on the top

of the coke ovens, there being one pipe for each oven, so that no flexible pipes need be used.

On a similar apparatus at the Cargo Fleet Works the conveyor truck carries its own motor, and the balanced receptacle for the coke can be raised and lowered by ropes and pulleys. While the coke is being pushed out of the oven past a quencher, the loader is moved slowly onwards so that the coke is evenly distributed in the receptacle, the small and breeze falling through the bottom grid into a bunker underneath, which is emptied at intervals. When full the loader is run to the railway truck which is to be loaded.

The loading machine consists of a substantial framework on wheels which runs on a track in front of the ovens. The raising and lowering of the balanced coke receptacle is accomplished by the same motor which drives the machine, and which is fitted below

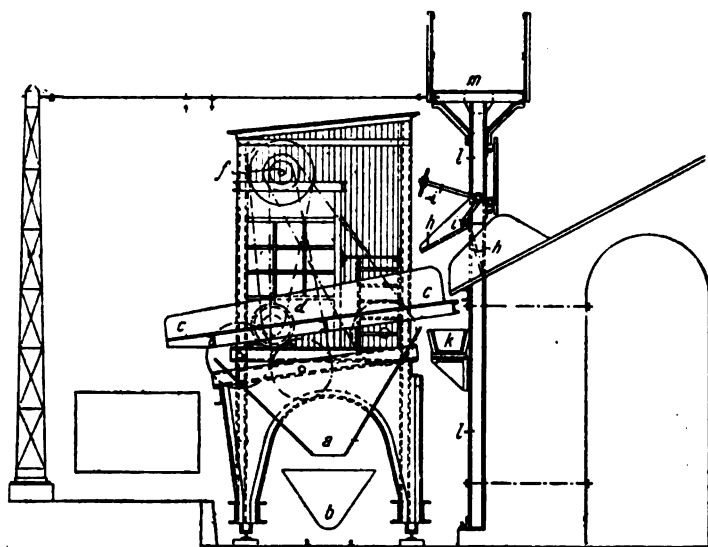


Fig. 613. The Humboldt Loader.

a. The bunker for small coke and breeze. *b.* The truck for the same. *c.* A balanced reciprocating screen. *d.* Electro-motor. *f.* Countershaft. *h, i, i.* Gate which admits the coke from the hearth, with adjustment. *k.* Trough for surplus quenching water. *l.* Steel standards supporting gate *h* and gantry *m* from which the coke is quenched.

the breeze bunker, together with its gearing and countershaft. The position of the motor under the receptacle being unfavourable on account of its being exposed to the moisture and heat of the load, a simplified form of loader has been installed to serve the ovens producing blast-furnace coke; in this case the bottom of the receptacle is horizontal. The quenching of the coke is completed by hand, and the coke itself is discharged by hand into the trucks for charging the blast-furnace.

Some of the latest coke loaders have been built in connection with short and steep hearths, where the coke is quenched completely on the hearth, and when cool transmitted by gravity on to the loading machine. There is a rail track for such special loaders, running between the hearth and the siding for the coal trucks. These appliances have been built to suit ramps sufficiently high above the coke trucks for the coke to be transferred to the loading device (between hearth and truck) by gravity.

An installation of this type, built by Humboldt, is shown in Fig. 613; it rests on four wheels.

A modification of the foregoing is the installation of F. Méguin, erected at the cokery of De Wendel at Gross-Moyeuve (see Fig. 614). The machine is supported and

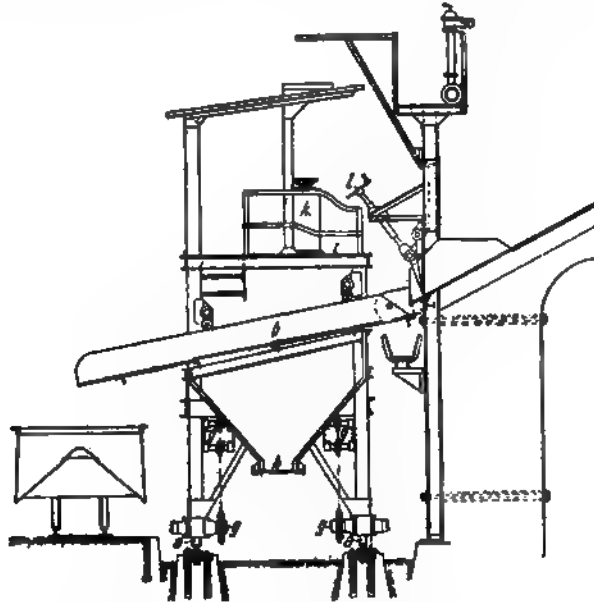


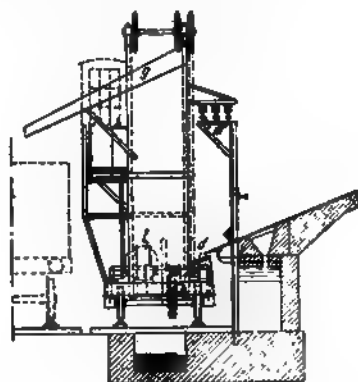
Fig. 614. The Méguin Loader.

a. Supporting wheels. *b.* Screen. *g.* Chain-drive for travelling gear. *h.* Adjustable gate to admit coke from hearth. *i.* Stand for operator. *k.* Starter for motor. *l.* Hand wheel for manipulating the gate for feeding the coke on the hearth.

travels on three pairs of wheels, the screen being about 15 ft. long by 6 ft. 6 in. wide.

In the foregoing installations the relative positions of the hearth and the siding are such that the coke is moved by gravity all the way to the truck, whilst in the following examples it has to be mechanically raised on account of the higher position of the coke truck siding.

The Brunck coke loader is a kind of scraper elevator which drags the coke up an inclined path into the truck (see Figs. 615 and 616). The machine is mounted on a travelling carriage on the standard rail track, and is used in connection with a short steep hearth which ascends again slightly to form a pocket for the accumulation of the coke ready for the loader. The diagram explains itself. Being mounted on a standard gauge the machine has the advantage that, in case of a breakdown of the loading device, the coke trucks may be loaded by hand on the track of the machine. The larger detail



Figs. 617 and 618. Fabry Coke Loader.

a. Scraper-belt. b. The structure. c. Three pairs of travelling wheels. e. Inclined portion of scraper conveyor. f. Bunker for small coke, covered with bar screen for the elimination of the same. g. Loading shoot. h. Return strand of scraper conveyor. i. Countershaft. k. Chain drive for conveyor. l. Electro-motor.

represents one of the buckets. Such a system is successfully at work in a French cokery.

The plant illustrated in Figs. 617 and 618 is the design of Mr Fabry, director of the Simplex Coke Oven Co., of Sheffield.

The two chains of the scraper conveyor are connected together at regular intervals by short lengths of chain. One of these machines can serve a battery of 100 coke ovens.

One of the coke loaders of the Coppée Company is shown in Fig. 619. Here the siding is practically on the same level as the lower end of the hearth, so that an excavated channel becomes necessary for the receiving end of the loading device. On the other hand a great amount of initial expense is saved by keeping the battery of ovens close to the ground, as no substructure is required.

At the Belgian coke ovens where this installation is at work, 100 tons of coke are loaded per hour, and only one man attends the machine. The motor for the conveyor is of 10 H.P., whilst that for the travelling gear is 20 H.P. The speed of travel is about 140 ft. per minute. The same firm have modified the design to suit local conditions, and where the space is confined a skip hoist has been used in a vertical position, manipulated by steel ropes.

Another class of loading machine dispenses with the coke ramp altogether. Such machines are exposed to heavy wear and tear, not only from the coke itself, but also from the great heat and the corrosion from the acid vapours, so that their construction is connected with many difficulties. As steel or wrought iron cannot resist these



Fig. 619. Coke Loader of the Coppée Company.

a. The elevator. *b.* The trench in front of the hearth. *c.* Girders carrying the overhanging receiving end. *d* and *e.* Electro-motors for elevator and for travelling respectively. *f.* Bar screen receiving coke from elevator. *g.* Delivery shoot. *h.* Bunker for small coke.

conditions, cast iron is used as much as possible in their construction, and especially for parts where the extra weight is of less consequence.

A machine of such a type was supplied about 1900 by the Wellman-Seaver Co. for the Lackawanna Steel Co.'s Works at Buffalo, U.S.A., to serve ten batteries with 940 ovens (Fig. 620). Two longitudinal walls are built in front of the ovens, and on these are placed open sheet-iron receptacles *a* (two for each battery) connected with the ovens by a platform *b*. Each receptacle holds a charge of coke, which is quenched from the platform, the surplus water draining away through the perforated bottoms into a gutter between the two walls, and through drain *c*. The track for the coke trucks is beyond the outer wall, and is served by a portable crane, provided with a running head *d* for tilting and discharging the receptacles. Two rigid arms *e* hook at *f* into eyes *g* on the receptacle, the hooks being locked by an electro-magnet *h*, to prevent a release before the proper time; at the opposite side the two hooks *f*₁ and wire ropes hold the receptacle, the hooks being likewise locked by the electro-magnet *i*, so that they cannot work loose; the ropes are protected by two telescopic tubes *k* against the

Fig. 620. The Wellman-Seaver Coke Loader.

vapours, as well as to prevent these whipping when wound on drum *l*. Two motors manipulated from driver's cab *m* serve for the travelling gear of the loader and for the manipulation of the receptacle. When the latter is filled with the contents of an oven, and after the coke is quenched, it is lifted approximately horizontally by means of the ropes, and carried by the crane to the empty truck, where the coke is loaded by tilting, as shown in the illustration. The apparatus has answered well, and the amount of wear is small, the only drawback being that the coke is not screened. Hence the device is restricted to works where the coke is consumed on the premises.

At the Lebanon Works of the same Company is a similar installation at work for two batteries of 232 ovens, for which also two of each four receptacles are in use. In these installations the appearance of the coke is of less importance, but the loading apparatus



Fig. 621. The Moore Quenching and Loading Machine.

of Moore, Philadelphia, effects the quenching and handling of the coke in a more careful manner, the air being excluded, and a silvery coke, resembling that from beehive ovens, is obtained. The device consists of an iron chamber as large as a coke oven, which is mounted on a travelling carriage operated by electricity (see Fig. 621). The chamber is enclosed in a shell divided into several vertical compartments *a*, with a short chimney *b* at the forward end, provided with a throttle valve *c*, the space between the compartment and shell being partly used as a water jacket. Strong doors at each end can be operated from the driver's stand *d*, the two sections of these double doors being opened and closed by ropes and pulleys *e*. An open slit is left under the front door for the escape of the surplus quenching water through a gutter *f* into the drain *g*. The coke falls down a shoot *h* into the railway truck. The two halves of the door next the oven fit against the oven door frames *i* when open. A lever *k* raises a small flap from the bottom of the chamber, to make a joint with the oven, and prevent the escape of water at that end; the flap is balanced by the weight *l*. The

quenching water is introduced from the hydrants by a hose connected with a pipe on the machine frame.

The working of the apparatus is illustrated in Fig. 622, in which *a* is the battery of coke ovens, *b* the coke pusher, *c* the quenching machine, *d* a stationary pusher at the end of the battery, and *e* a railway truck, belt conveyor, or screen. The machine is placed in position opposite the oven to be emptied, the chimney valve is closed, and the water pipe connected with the hose; the door next the oven is then opened, and the chamber is filled with coke, the rear door is closed, and the water turned full on for several minutes, until it begins to drain away freely, whereupon the supply is shut off, and the machine is run along to the stationary pusher, where all the doors are opened and the coke expelled into the truck opposite.

An apparatus of an entirely different type to all the foregoing is that of Illig, made by A. Bleichert & Co. (Fig. 623). Close in front of the oven doors is a longitudinal water trench *a*, over which travels a steel

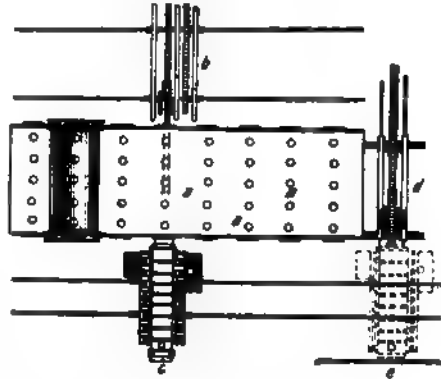


Fig. 622. General Arrangement showing an Installation of the Moore Machine.

tower *d*, with a suspended receptacle *b* with sloping bottom, preferably of perforated sheet iron, and fitted with a sliding door *c* on the side remote from the ovens. This receptacle is slung from two chains, adapted to be wound on drums in the upper portion of the tower by motor *e*. The winding and travelling motors are reversible, and are operated from the cab at the top of the machine.

A double overhead runway *g*, *g*₁, with rounded ends, and supported by two structures *f*, is provided at the rear of the machine, and conveys the skips *h* from the quencher round to the trucks. The skips (Fig. 624) are suspended from a bent arm *a* attached to the wheel truck *b*, which is operated by an enclosed motor. The skip is slung on two wire ropes adapted to be wound on a double drum *c* by means of a second motor. Current is supplied to both motors through a live wire *f* and collector *g*. The skip is closed by bottom flaps *h*, *h*, operated by a lever *i*, provided with a contact piece. The motors are switched in and out of action by portable switches, which enable the skips to

Fig. 623. The Illig Coke Loader.

be stopped and discharged at any desired point, and also to run at definite intervals. Two men are sufficient to work the plant, and the *modus operandi* is as follows: The quenching machine is put into position in front of the oven to be discharged with the receptacle up, which is, however, lowered immediately the machine is in position; the coke is then pushed into it and thoroughly quenched. After this the machine is moved aside to enable the oven door to be luted up, the receptacle is raised again, the attendant turns to the runway, on which the empty skip is waiting, switches on the lifting motor, which lowers the skip, the latter being then filled automatic-

ally from the receptacle, raised again, and moved off on the runway. Meanwhile the man at the discharging station has set his switch to discharge the oncoming skip into the desired truck. The trench is covered to prevent accidents, and to keep it clear of coke droppings, by a travelling cover of corrugated plates, running over hexagonal drums at each end, and fixed on to the quencher in such a way as always to completely cover the trench; also when the quenching receptacle is travelling in either direction, one of the terminal drums of this cover is driven by an electric motor by worm and pinion gear, the speed of travel being 18 ft. per minute.

This system has been further improved and simplified by using the quenching receptacle at the same time as a skip, and delivering the coke direct either over a sieve into a bunker, or into railway trucks, in order to dispense with the separate loading device. Such an installation is shown in Fig. 625. This illustration shows a section through the pit or canal in front of the battery. The water receptacle *a* is here portable on wheels, and is divided into two compartments *b* and *c*. The perforated quenching vessel *d* is suspended from a cable *e*, and when moving along the canal drags the water receptacle *a* with it. The funnel *f* is shown in position before the oven to be pushed, so that the coke falls through this into the quencher. When this has received the contents of the oven, the whole apparatus is drawn by the cable *e* to the end of the battery where the water tank *a* remains stationary, whilst the quenching vessel *d* ascends out of the water, guided by *g g*, and discharges into bunker *h*, after which it returns in like manner to the next oven to be dealt with. The great advantage claimed for this system is that the quantity of quenching water used is the smallest possible, and as the water is always at a high temperature, the percentage of moisture in the coke becomes less, as the residual heat in the latter evaporates the adherent moisture more readily during transit from pit to bunker.

Fig. 624. The Skip of the Illig Loader.

Stole, of Farlowitz, in his latest coke plant (Fig. 626), has adopted a water trough or canal similar to the installation shown in Fig. 623, but the channel is not for quenching purposes in this case, but to float the hot coke receptacles, like boats, to the quenching tower, a power-driven water wheel creating the necessary current for the conveyance of the coke receptacles. The *modus operandi* is as follows: A floating receptacle is placed in front of the oven to be pressed, which receives the charge which is superficially quenched under a water spray. The vessel is now released, and the final quenching proper is not performed until the floating skip reaches the quenching tower *a*. Here it is emptied on to a grating *b*, and completely quenched by the quencher *c*; the shoot *d* is now lowered and the coke is raised by the lift *e*, either for classification, or into railway trucks, leaving the breeze beneath the bar screen. Since the skips float rather deeply in the water, they do not

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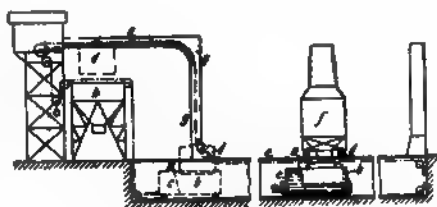


Fig. 625. The Coke Quencher and Loader of Bleichert.

suffer to any great extent from the hot coke. So far this system has only been used in *cassworks*, but it is also to be adopted for coke ovens.

Lastly, we have to deal with those appliances or which there is no hearth necessary at all, and in which quenching, sifting, and loading are performed as a continuous process. An installation of this type is that of 'Méguin' (Fig. 627). The machine is mounted on wheels and runs along the front of the ovens on rails. The coke is rushed past a long quencher *a* consisting of a network of spraying pipes, and over a sloping shoot into a hopper *b*, through the adjustable shoot, off which the coke falls on to a travelling band *c*, the lower terminal of which dips into a water tank *d*, so that the coke is thoroughly quenched on its way to the screen *e*, which delivers the large coke on to a shoot leading to the railway track, whilst the screenings are discharged into a special hopper. The overflow water from the quenching tank runs into a drain extending the whole length of the battery, the tank being replenished with water from a trench *f*, by means of a centrifugal pump *g*, coupled direct to the motor operating the machine. Since the conveyor *c* is sufficiently long to hold a full charge from one oven, the machine, when filled, can be run to any part of the track for discharging into trucks, so that all shunting is dispensed with. For blast-furnace work, the machine discharges into hoppers, from which the charging skips can be loaded.

A modified form which was successfully installed at the cokery of the Soc. des Mines de Béthune, Bully (Fig. 628), consists of an inclined conveyor delivering the coke to a

Fig. 626. The Coke Handling System of Stole, of Barlowitz.



Fig. 627. Showing the Portable Quenching, Sifting, and Loading Machine of Méguin.

screen forming a part of the machine and loading it direct into trucks. The coke is exposed to the action of a quencher, and the work is afterwards completed on the

conveyor by additional jets. The sections of the conveyor are made of perforated sheet iron, with side plates 12 in. high. It consists of three chains connected to each other by cross-pieces, and a narrow gangway for the attendants is provided on either side. The delivery end of the machine is provided with a jiggling screen, and the whole is mounted on a substantial frame running on wheels in front of

Fig. 628. The Méguin Machine at the Coke Works of the Mines de Béthune in Bully les Mines.

the battery. The quencher and loader are moved from one oven to another by a slewing crane, operated from the main motor by ropes; and a contrivance with intermittent motion, between the quencher and conveyor, enables the coke to be spread out for completing the quenching.

Another somewhat different type is the machine of Kellner & Flottmann, of Düsseldorf, used at the Herne cokery of the Hüstener Gewerkschaft (Fig. 629). In front of the short ramp *a*, and about 6 ft. lower, is a second broader level *b*, with the rail track for the machine. The apparatus, like those formerly described, is self-contained; the floor, as it

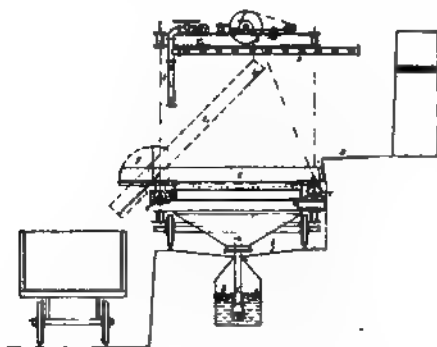


Fig. 629. Coke-Handling Machine of Kellner & Flottmann (Schumacher System).

were, of the machine consists of a grating *c*, the bars of which are attached to two frames in such a way that those secured to the frame *c* can alternately be raised and lowered by means of a drum *f*, whilst the intermediate bars remain stationary. The screen is operated by eccentric shafts *d* and *e*, on which the screen frames are loosely mounted in guides *d*. On the side away from the ovens the screen has a

cast-iron hinged extension *g*, which is lifted up while the coke is being received, but falls down automatically when the screen is tilted, and forms a shoot for the discharge of the large coke to the trucks. The screenings fall into the hopped bunkers of perforated plate in the underbody of the carriage, to allow the quenching water to escape. The water is drawn from a conduit *h* below the track through a suction pipe *i* by means of a centrifugal pump, which delivers the water to a series of sprinkling pipes *k* above the screen. The machine deals in each operation with the whole charge of one

of the ovens, which may be loaded into any of the railway trucks in waiting by raising the grating *c*¹, as shown in dotted lines. The agitation the coke receives from the bar screen not only disposes of the breeze, but it loosens the coke slightly, and with a minimum of breakage, for the easier access of the quenching water to all parts, and a more uniform cooling. The screenings are delivered at intervals to a classifying plant at the end of the battery. The whole machine can be worked by one man, and is operated by a 35 H.P. motor, a 6 H.P. motor driving the pump.

The latest machine which automatically receives, quenches, screens, and delivers the whole charge of an oven into any available truck along the whole line of coke ovens, is that of Goodall, and was erected for the Weardale Steel, Coal, and Coke Co., Spennymoor (Figs. 630 and 631). The machine consists of a large iron frame running on eight wheels, on rails placed in the position usually occupied by the

Fig. 630. Elevation and Cross Section of the Goodall Machine as Manufactured by W. J. Jenkins & Co., Ltd., of Retford.

bench or quenching floor. It is fitted with motor and gearing to propel it along the rails in either direction, and to revolve the table or coke receptacle, and drive the shaking screen. In the centre of the frame there is a substantial cast-steel footstep bearing, which receives a short vertical spindle. From this axle, leading to the periphery, horizontal girders are fixed which are connected at their extremity by a cast-steel ring having teeth at its lower edge, and forming a large wheel which gears into a pinion on a horizontal shaft. Below this turntable there is a rail bent into a ring-form, which gives the table support and stability, by means of a ring of rollers running on the same. The framework of the table so formed is covered with interchangeable perforated cast-iron plates, to form a revolving table 20 ft. diameter to receive a charge of coke; the table is surrounded by plates, which are also lined again with interchangeable cast-iron plates up to the height of 3 ft. There is a slot-like opening, with guide plates, in this outer cylindrical ring on the oven side of the machine, sufficiently large to allow the cake of coke to enter. Directly opposite this

opening is a large door in the same cylindrical casing, manipulated by a winch and chains in such a way that when the door is closed the inside of the casing is a complete ring, but when open the door projects inwards and reaches to the centre of the turntable, and being fitted with plough-shaped castings on the back, acts as a scraper to remove the coke from the revolving table. Under the doorway is arranged either a fixed or jiggling screen, and the coke coming from the table falls on to the screen and passes thence, properly screened, into the railway wagon. A receptacle below the screen, which is emptied periodically, receives the breeze and small. Above the revolving table, as well as down the sides of the cylindrical casing, is a net of water pipes, perforated to act as sprays for quenching the incandescent coke, and a small hose for spraying water by hand is also provided, to play in any direction that may be necessary.

The method of working the machine is as follows: First, the huge apparatus is driven along the rails and placed opposite the oven to be discharged; the oven door and the receiving slot having first been opened, the pushing then commences. As soon as the red-hot cake of coke enters the machine the water is turned on and the quenching begins. When the coke has reached about one-third across the table, the latter is caused to revolve in the direction of the clock. The coke then rests on the table, and the continued motion of the latter, combined with the continuous forward motion of the cake of coke, gently promotes the distribution of the contents of the oven over the revolving table,

Fig. 631. Plan of Goodall Machine shown in Fig. 630.

the quenching operation proceeding all the while by water being sprayed on to the coke both from above and sideways until at last all the coke is on the table, which is now stopped and the machine moved a few feet out of the way so that the oven door may be put on at once. The water is now shut off, and a reasonable time allowed for steaming and drying, say ten minutes, after which the table with its load of coke is slowly revolved, and the attendant with his hand hose sprays water on any red places until the whole of the coke is quenched. Surplus water drains away immediately through the perforated plates in the table, and so avoids over-wetting of the bottom coke. The small breeze which passes through with the quenching water collects in large bins between the rail track, divided off transversely by walls; here the breeze settles at the bottom and the water percolates through to a drain, so that the remaining breeze may be collected from time to time.

The quenching being completed after about ten minutes, the flexible water connection between the fixed main and the machine is disconnected, and the same is propelled along



Fig. 682. The Goodall Machine, showing the Coke being Screened and Loaded into Wagons.

the rails to any waiting wagon, either in front of, or some way beyond, the oven from which the coke came. The discharging door is then opened a little way, at first inwards, and the table revolved in a counter-clockwise direction; the coke is, in consequence, gradually pushed out by the plough-like door on to the screen, which is set in motion by means of gear from the motor, and the screened coke is automatically loaded into the wagon (see Fig. 632).

One of the important features of the system is the expeditious way in which the coke is handled. The time occupied from the start of the push to the time when the door is on the oven again ready for recharge is only eight minutes, and the whole operation, from the beginning of the loading into the wagon, including the steaming or drying period, does not require more than twenty-seven minutes.

The principal advantages of this machine are its great simplicity, in spite of its automaticity (the weight being only about 28 tons), and the fact that the hot coke comes only in contact with renewable cast-iron plates, a material which is least affected by it.

The installation of the Weardale Steel, Coal, and Coke Co., at Spennymoor, serves a battery of sixty ovens, with a yield of 1,700 tons per week, and is attended by two or three men only, as against twenty-one to twenty-seven when the coke was quenched and loaded from an ordinary hearth by hand. In addition

Fig. 633. Méguin Modification of Goodall Machine.

a. Travelling frame. *b.* Bunker for breeze. *c.* Breeze trucks. *d.* Annular receptacle for surplus quenching water. *e.* Waste-water pipe from *d.* *f.* Waste-water gutter. *g.* Vapour duct. *h.* Iron rim which prevents the coke from falling out at the side. *i.* Grating for eliminating fine coke. *o.* Loading shoot.

to this advantage, the breakage of coke is less by $\frac{1}{2}$ per cent., and the moisture contained is below 2 per cent.

The machine is driven by a three-phase electric current from the central station close to the works, but it is, of course, equally adaptable for steam power.

The Goodall principle has been modified by F. Méguin & Co., of Dillingen, as illustrated in Fig. 633. In addition to the alterations, which may be seen from the diagram, the scraper for discharging the coke has been so modified that it is actuated by the revolving table. The lettering given under the illustration will

explain the diagram, after the full description which has been given of the Goodall machine.

Some of the latest coke-handling plants have been designed with a view of excluding the air more effectually during the quenching process, to produce coke of silvery colour as obtained from the old-fashioned beehive ovens.

The first installation on these lines as already mentioned (Fig. 621) was that by Moore, erected in an American cokery. The machine has been simplified by Humboldt. The quenching chamber into which the entire contents of an oven are pressed is enclosed and filled with vapour or steam created during the quenching process, so that the air is completely excluded, and the quenching apparatus proper is suspended within the interior of the receptacle. As soon as the cake of coke is completely enclosed and quenched the apparatus is driven to the end of the battery where it is tilted sufficiently for the coke to slide out by gravity, either over screens and into trucks or on to conveyors. The quenching water is pumped by the apparatus from an open water trough by a centrifugal pump, and the surplus water is returned to a similar trough, and after passing a settling tank the clean water is returned into the first water trough again. With such an installation, it is obvious that the coke siding cannot be in front of and parallel with the hearth, but must be at right angles, and at the side of the battery. The whole machine is mounted on twelve wheels running on three rail tracks at a speed of 160 ft. per minute, and only one man is required to attend to the machine, which is capable of serving a battery of one hundred ovens.

A still more effectual exclusion of the air is obtained by complete submersion of the coke in water. This process has been in use for some time in gasworks, but it has lately been applied on a larger scale to coke ovens with great success. An essential feature of the process is that both coke and quenching water leave the machine at so high a temperature that the moisture still adhering to the coke is evaporated by its latent heat.

During the experimental stages, when submerging large quantities of incandescent coke, explosions occurred sufficiently violent to throw the coke and water out of the quenching receptacle, but, as might be expected, it has been found that if the coke is slowly submerged so that the steam can escape through the interstices of the incandescent coke, these explosions do not occur, and the coke so quenched is of a firm quality and in large pieces. This is explained by Schöndeling, the pioneer of the system, to be owing to the gentle action of quenching; the steam rising from the portion first quenched being superheated, by passing through the still incandescent coke, to such an extent that the difference of temperature between the coke and the quenching medium is comparatively small, and its quenching action very gradual, whilst chilling the coke from above will contract it suddenly and make it brittle.

The first plant on the Schöndeling system was erected in 1910 at the Gasworks, Agram, in Germany, and a typical installation of the kind is shown in Fig. 634.

The coke receptacle *a* is composed of double walls, and takes the whole charge of an oven. There is a communication between the double wall space and the lower portion of the receptacle, so that the little water contained at the beginning in the space between the walls will quench the coke in the bottom of the receptacle; the quenching tanks *d* are large enough to contain sufficient water to quench three or four charges without replenishing.

When the oven door has been opened and the machine placed in position the pushing is commenced, and the coke enters through the passage *e* into the coke receptacle *a*, which rests in the water tank *k* during the filling. The quenching process

takes place slowly from the bottom upwards until the whole of the coke is submerged. The receptacle or skip *a* is now slowly raised and the water allowed to run out of side openings into the water tanks *d*; when the water has run off the skip is raised further, and tipped automatically by rollers and guides (as shown in dotted lines) on to the screen *g*, and thence to the truck.

The same machine is built in different ways. In some installations the skips are detachable, and are placed on a wheeled base and conveyed thus intact with their load to

Fig. 634. Schündeling System for Quenching and Loading Coke.

a. The coke receptacle. *b*. Winding gear for lifting and lowering the receptacle. *c*. The steam or vapour duct. *d*. Two quenching water receptacles (communicating with each other). *e*. Shield between oven and quenching apparatus. *f*. Flap which bridges over the gap between the oven door and the apparatus. *g*. Screen on which the coke is emptied. *h*. Receptacle for small coke. *i*. Rails on to which the apparatus runs. *k*. Water receptacle in which *a* stands whilst receiving a charge of coke.

where the coke is required. In some machines the tank *k* is dispensed with, and the water enters into the space between the double walls of the skip from the tank *d*; when tank *k* is used the skips are generally of single iron sheets, and not double walled. In some machines the skip is balanced by counter-weights. Two men only are necessary to manipulate such a plant, and with it are capable of handling the contents of six or seven ovens per hour.



UNLOADING AND LOADING APPLIANCES

CHAPTER XXX

DISCHARGING BY MEANS OF SKIPS, GRABS, AND LIFTING MAGNETS

BOATS and barges as well as railway trucks usually deliver material at the point where the mechanical appliances for its further conveyance are located, and here the transfer has to take place. Hand labour at this point is out of the question if the plant is to be economical, or if labour-saving devices can do the work wholly or even partially. Perhaps the most frequently used appliances at this stage are skips and grabs.

To operate any kind of bucket for unloading purposes a crane of some description is necessary, such cranes often being fixtures on the quay side, and when large vessels have to be discharged they are used in pairs or in even greater numbers. Not infrequently they are mounted on rails in order to be readily moved to any point on the quay at which the boat to be unloaded may most conveniently be moored.

It is not, however, so much the object of this chapter to give a technical description of cranes, as to deal more in detail with such skips and grabs as are manipulated by cranes, telfers, and transporters.

The oldest form of skip consists of a bucket suspended slightly below its centre of gravity by an arched bail with a catch, which keeps the bucket in an upright position. Such buckets have a capacity of from 1 to 3 cub. yds., and are lowered into the boat and there filled by hand. When full, they are raised by the crane and swung to the unloading position, when, the catch being withdrawn, the buckets tilt and discharge their contents. This mode of unloading is used for grain as well as for minerals, but has to a great extent been superseded by the self-filling grab, as the latter dispenses with hand labour in filling.

Grabs are frequently used for excavating purposes, perhaps as much so as for handling grain and minerals. Although the earliest grab known only dates from 1703, there is every reason for believing that appliances of this type were in use at an even earlier period. In 1703 the French Academy of Science approved of the design of a machine for excavating purposes, a description of which was published by them. This appliance was the invention of a M. Gouffe, and had the outward appearance of the modern grab. It was provided with serrated edges that cut into the ground, and was operated by two ropes and a bar which gave the cutting edges a downward pressure, the two ropes being manipulated by two windlasses. There are other designs too numerous to mention which have from time to time sprung up, only to disappear again. The grab of to-day is perhaps one of the most familiar of modern labour-aiding devices.

Self-Dumping Buckets.—Before passing to a more minute description of grabs, one or two types of mechanical self-dumping buckets may be mentioned, one of which

is illustrated in Fig. 635. These generally consist of a large tub with hinged bottom doors; such appliances were used at the Millwall Docks for unloading grain before the Duckham pneumatic elevator came into use. These tubs have the advantage of being light, as they hold 60 bushels of grain, or nearly 3 cub. yds., and weigh only 5 cwt. The bottom is divided into two halves which are hinged to an iron bar traversing the bottom of the tub, and the lower edge is so contracted as to form a truncated cone 6 in. in height; thus the diameter of the lower portion is 1 ft. less than that of the main portion of the tub.

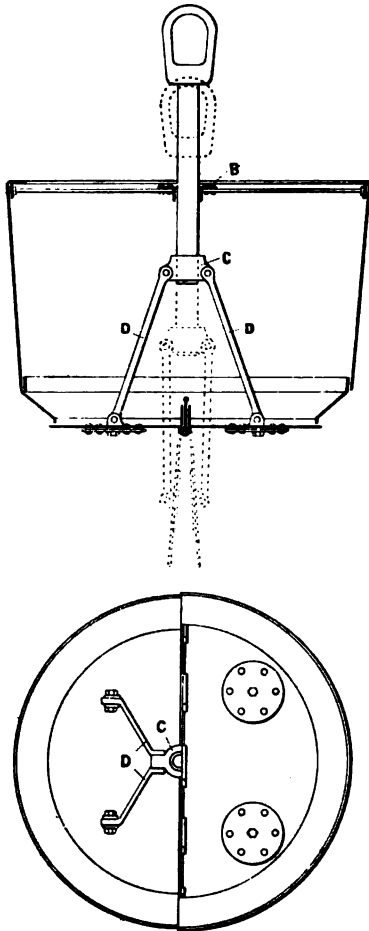


Fig. 635. Mechanical Bucket formerly in use at the Millwall Docks.

The lower rim is so machined as to fit the hinged bottom. The bucket is suspended by a length of $3\frac{1}{2}$ -in. wrought-iron tubing passing through the bearing B, and having a suspending eye at the top and an attachment c for four connecting rods D at the lower end. When suspended from the eye the bottom door supports the shell portion of the tub. When filled the tub is lifted by the crane and deposited on a circular opening in the top of the receptacle where the load is to be discharged, and as the crane continues to lower, after the shell of the tub has reached its seat, the doors open (as shown in the dotted lines) and the grain discharges. The doors shut automatically as soon as the crane lifts the empty bucket off its seat.

Self-Discharging Skip of Taylor & Hubbard.

—This is similar to the foregoing appliance, as will be seen by Fig. 636. It must be filled by hand as is the previous one, but discharges its load automatically, after the manner of a single-chain grab described later. The automatic gear A, which is suspended from the jib-head of any crane, discharges automatically at any predetermined point to which the gear may have been raised or lowered. The mechanical working of this apparatus, which can be manipulated by one man, is clearly shown in the illustration.

The flaps forming the bottom of the skip are connected by links F F to the rod C, which is attached to the lifting chain, while the body of the bucket has connected to it a sleeve H, through which the rod C passes, and which has a conical top with a shoulder H². The automatic gear is

independent of the jib. Bell crank triggers J, adapted to engage the shoulder H², have projections j¹ sliding in slots in the sleeve A, and are normally pulled upwards as shown by springs a¹. Projections engaging slots in the part A limit the lateral play of the triggers J. On raising the loaded bucket the triggers J are forced apart by the conical end of the sleeve H, and then close under the shoulder H² as shown. On lowering, the weight of the bucket pushes the triggers down so that their horizontal arms engage projections k¹ on the arms K, which are forced inwards by springs, and on further paying out the chain the bottom of the bucket opens. The bucket itself is

supported by the triggers J. In lifting, the weight of the bucket is again taken by the chain. The triggers turning on the fulcrums J¹ are pulled outwards by their springs, so that on again lowering, the sleeve H drops, and its shoulder H² engages the arms K, releasing the triggers J, and allowing them to return to their normal position ready for the next operation.

An intermediate form¹ between the skips just described and the grab is illustrated in Fig. 637, which shows the jaws in an open and in a closed position. This appliance was used for a variety of purposes—for unloading minerals and grain for instance—in which case the receptacle was filled by hand, and then swung by means of the crane into position in order to deliver to the spot at which the discharge was required, when the contents were deposited by means of the two outer chains. It will be readily seen that the discharge of coal from this appliance was more gentle than from the skip previously described.

In the earliest grabs, owing to their slow speed of working, chains were used for lifting and closing the jaws. The higher speed at which grabs are now worked makes chains unsuitable on account of the greater wear, their noisiness, and their liability to break without giving any warning.

Generally speaking, ordinary chains are rarely used, but mostly those of special design are employed.

Grabbs may be roughly divided into two sections—those working with one rope and those with two or more. The inducement for the employment of one-rope grabs is that existing cranes can be used to manipulate them, while for two-rope grabs it is necessary to install a special winding gear on the crane in order to accommodate and

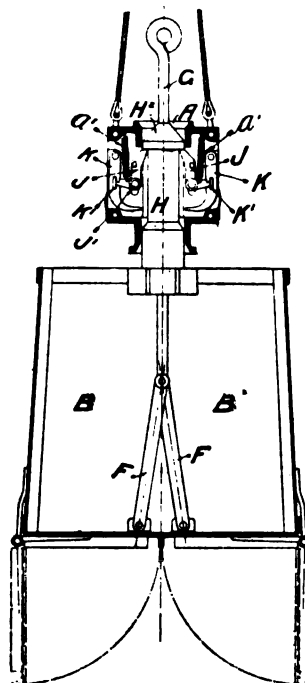


Fig. 636. Self-Discharging Skip of Taylor & Hubbard.

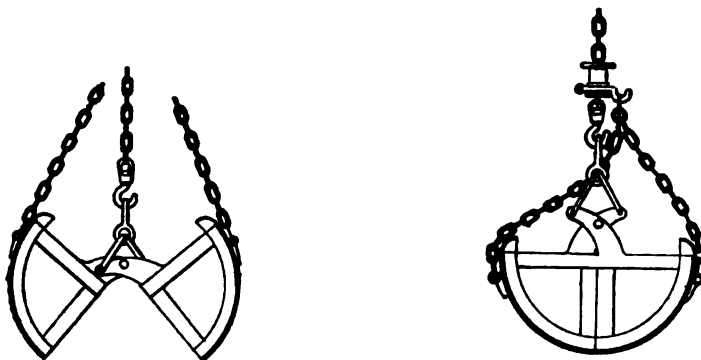


Fig. 637. Self-Discharging Skip with Semicircular Jaws.

separately actuate the two ropes. With a one-rope grab the single rope when tightened will first close the grab and then immediately lift it. The cycle of movements in the one-rope grab is practically unalterable. It is lowered open upon the material, closed and

¹ *Magazine of the Thames Ironworks*, June 1900.

lifted and discharged suddenly in its highest position by a catch which releases the grab so that the material by its own weight forces the grab open, and so escapes. The disadvantage of these appliances when handling friable material such as coal is obvious, particularly when used for forming stock piles. When the pile is high the damage to the falling coal is not so great, but as the point of discharge cannot well be altered, the coal has to drop a considerable distance when the pile is low. Another disadvantage is that one-rope grabs are generally heavier, more costly, their centre of gravity is higher up, and they are, therefore, more liable to tilt over when lowered on to the material.

The two-rope grabs, which have a separate rope for lifting and for discharging, although they require more expensive winding gear, have the advantage that they can be gently opened and discharged at any height, and they may be lifted or lowered when open. In case of breakage of one of the ropes the grab would still hang by the other. With such grabs the two ropes should be the same size, as during the discharge the full weight rests on the second rope instead of on the hauling rope.

Experiments have shown that the greatest resistance to the movements of the jaws is towards the end of the closing motion; it is therefore advisable in the construction of grabs to choose means for the transmission of the power, to give the second half of the closing motion the greatest power, such as may be produced by the closing of toggle levers.

The desire to build grabs which not only open wide but have a scraping and gathering action has led to the introduction of a compound movement for the jaws. If hinged at a stationary point the jaws of a grab are bound to describe a segment of a circle with their cutting edges, whereas the path of a grab with compound movement describes a curve more like an ellipse, which increases its gathering and filling actions. These have generally so powerful a closing action that even large pieces of ore can be crushed in order to accommodate them in their jaws. Grabs of this description are those of Hoover & Mason; Hulett (which is built by the Wellman-Seaver-Morgan Manufacturing Co.); the Temperley grab; and that of the Brown Hoisting Machinery Co. (*q.v.*).

When unloading railway trucks and small barges, grabs should be used only for material that can be easily handled by them, such as grain, coal, coke, etc. With heavy materials which are much more difficult to handle, the weight of a suitable grab would be so great that the receptacle to be unloaded might suffer damage.

"Orange-peel" grabs are not suitable, as they are liable to cause injury by their sharp points; it might also be mentioned that they are heavier and more expensive than a two-jaw grab of the same capacity. They are most suitable for excavating purposes, such as for sinking wells, etc.

Grabs hinged at the haunches, that is from the extreme outside of the frame, get a greater leverage, and therefore a more powerful closing of the jaws, and so are the most suitable for large pieces of hard material.

Salomon's Experiments with Grabs on Dry Sand.¹—A series of observations have been made by Mr B. Salomon, the results of which were published in the *Zeitschrift des Vereines deutscher Ingenieure* in 1886.

He found that the resistance of the grab as dug into sand increased with the depth to which the grab penetrated, and he maintained that his experiments taught him that this increased resistance is also essentially dependent upon the shape of the grab jaws, or rather on the position of the fulcrum to the radius of the curve of the jaw.

Perhaps the simplest way in which to explain the results of these experiments is to

¹ Dingler's *Polytechnisches Journal*, 2nd May 1903, pages 283 and 284.

imagine a flat, very thin, and perfectly smooth spade dug into sand in the direction of its plane. In that case the only resistance caused will be to the progress of the cutting edge of the spade, that is to say, to its cutting action, because the grains of sand lying directly in the path of the blade are pushed to one side.

But suppose the blade of the spade to be thicker and somewhat curved, like the jaws of a grab, then it will displace a certain amount of sand which must be pushed aside in proportion to the depth of the curve. In such a case the sand will either be compressed, or, if the blade does not enter a great depth, the sand displaced will be pushed outwards on the oblique side of the spade in the direction of the line AB (see A, Fig. 638). According to the resistance of the sand the line AB forms an angle γ with the horizontal. The angle $\gamma = 45^\circ$, assuming $\frac{X}{2}$ to be the natural angle of repose of the material. The resistance thus set up increases very considerably should the surface of the spade or jaw be rough, and, as shown in A, Fig. 638, the sand is heaped up as the spade enters the ground, being displaced by the body of the spade. A similar resistance is felt on the other side of the blade, to which must be added the friction between the blade and the sand.

So far it has been assumed that the sand was level on either side of the blade, and

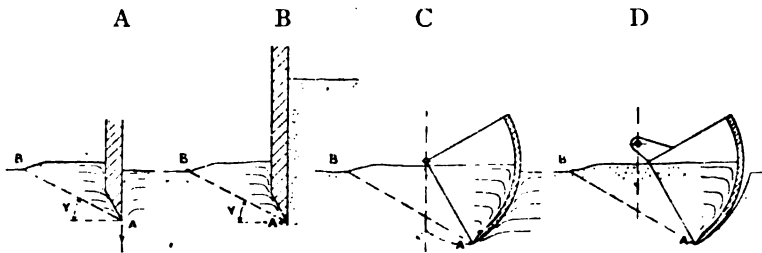


Fig. 638. Diagrams showing Action of Grab.

that the blade entered vertically, as shown in A, Fig. 638; but if B, Fig. 638, is accepted as a truer picture of what actually takes place, namely, that the sand is heaped up much higher on the right or interior side of the grab, then it is obvious that the resistance is greater on the right side.

According to Mr Salomon, the total amount of resistance can be considerably lessened by a judicious shaping of the digging blade. A grab with cylindrically shaped jaws was therefore chosen, the axis of rotation coinciding with its radius (see C, Fig. 638). Even with this there will be a considerable amount of resistance on the outer walls of the blade, because the material lying below cannot escape, but must be compressed. Salomon found that when the axis of rotation was placed slightly above the centre of the radius of the blade, as in D, Fig. 633, the outer resistance was diminished, and the internal digging power of the jaws increased. The sum total of these experiments, although of small practical value, point to the advisability of slightly raising the axis of rotation of the jaws.

It was, however, judiciously pointed out by Baron Hanffstengel that in these experiments the point of rotation was fixed, and that on that account a fairly great pressure between the sand and the grab jaws could be set up, whereas in practice the total vertical pressure cannot at the most exceed the weight of the grab with its contents, and will probably be less, as a portion of the weight is held by a chain.

Mr Salomon says that the higher the point of rotation is removed from the centre,

the greater the power necessary to raise a given quantity, on account of the compression of the material between the two jaws of the grab, as may easily be understood from Fig. 639. No doubt the amount of matter scooped up increases in proportion as the gripping point is raised, but the difficulty of closing the jaws is proportionately increased.

Instead of shifting the action of rotation in this way it would in many cases be more advantageous to form the cutting edge of the blade in a straight line instead of a curve, as shown in Fig. 640, as in such a case the blade will penetrate into the material better at the first onset.

If the weight of the grab be insufficient, the jaws will have a tendency in closing to lift themselves out of the material after having sunk to some depth, while the cutting edge of the jaws will describe, instead of an arc, a curve as shown in the dotted lines A C, Fig. 638, C, and in consequence the grab will not take its full load.

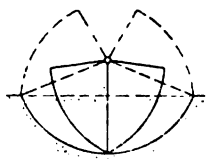


Fig. 639.

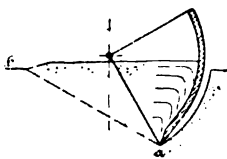


Fig. 640.

The illustrations give a clear representation of the movement of the jaws of ordinary grabs hinged at or near their centre, but what

has been said does not refer to grabs which are hinged from their haunches. In that case the action is different altogether, as the filling of the grab does not depend in the first instance upon the jaws entering the material to some depth through the drop of the grab from a certain height, but depends entirely on a scraping action which will be understood from Figs. 641 and 642, the latter showing not only the scraping but also the closing action of the toggle levers.

The Efficiency of the Grab.—The useful effect of a grab depends to a great extent not only on the shape of the jaws but also on the nature of the material to be

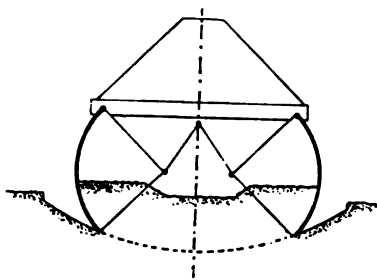


Fig. 641.

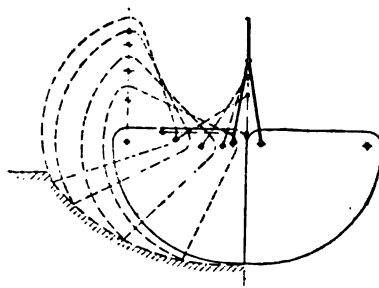


Fig. 642.

handled. The jaws of any grab will more readily handle a light material of a uniform size than one which has a greater specific gravity and contains large pieces. There is no difficulty whatever with most kinds of grabs in the handling of grain, sand, small coal, etc., but when dealing with a material like iron ore a grab which would fill to its full capacity on the former materials would barely fill to half its bulk capacity on the latter.

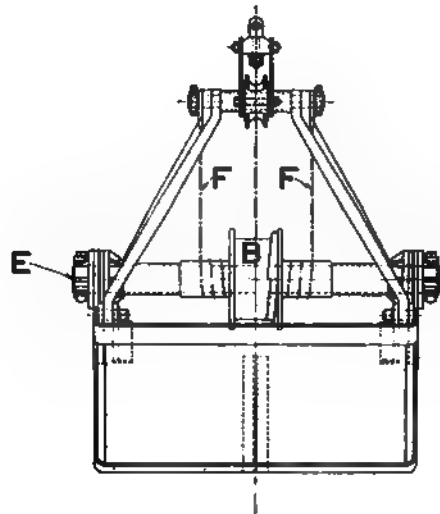
The angle of repose of the material is also an important factor in the filling process, as the greater the angle of repose the more difficult it is to gather the material into the grab.

It has also been maintained that the handling of coke or coal by grabs was detrimental on account of the breakage which was deemed inevitable; but there is really no need for such breakage if a grab of suitable construction and design is used. The

grab is often dropped down on the material, which is bound to break under its weight, but there is no occasion to do this with any grab, as it makes little or no difference to the amount raised. They will fill just as readily when laid gently down on the material, as the action is in this case a gathering one, and the grab buries itself in the heap. With grabs used in this way there need be no more breakage than in filling skips by hand.

The Priestman Grab was one of the first to be placed on the market in this country. It was originally operated by two chains, one for closing and hoisting, and the other for opening.

An ordinary design of "Priestman" Grab is illustrated in Figs. 643 and 644. *A* is the hoisting and closing chain, which is fixed at one end to the drum *B*, and at the other to the crane hoisting barrel. The opening chain (or frequently wire rope) is attached to



Figs. 643 and 644. Priestman Two-Chain Grab.

the head of the grab at *C*. The two jaws *D D* are hinged together by the strong central shaft *E*. The method of operation is as follows: The opening rope is held by the brake, and the hoisting chain is paid out; the shaft *E* thereupon falls, and the jaws open, as shown in dotted lines (Fig. 643). The action of opening unwinds the side chains *F F* from the two ends of drum *B*, and this winds a short length of hoisting chain on to the centre portion of the drum. The grab is then lowered open on to the material to be lifted, and the opening rope being released, the hoisting chain is wound up, thus causing the side chains *F F* to haul up the top shaft *E*, thereby closing and filling the grab. On further winding up the chain *A*, the grab is lifted with its load to the place of discharge, and is emptied in the manner already described. It will thus be seen that if the full weight is carried on chain *A*, the grab is closed, and if from point *C*, it is open.

To increase the digging power, a multiple arrangement of sheaves is frequently fitted in place of the drum *B*, and different designs of jaws are provided for handling various materials.

In working two-rope grabs, cranes specially designed for the purpose should preferably be employed in order to obtain the best results. As, when grabbing, the question of

output is generally of the first importance, it is obviously best, in order to make the installation economical, to have a crane which will operate the grab at the highest speed, even if the first cost be somewhat greater.

Fig. 645. Example of Crane and Grab.

The "Priestman" grab crane, as shown in Fig. 645, has been designed to meet these conditions. Normally seventy to eighty lifts can be made per hour, or probably nearly twice the number obtainable with some ordinary cranes.

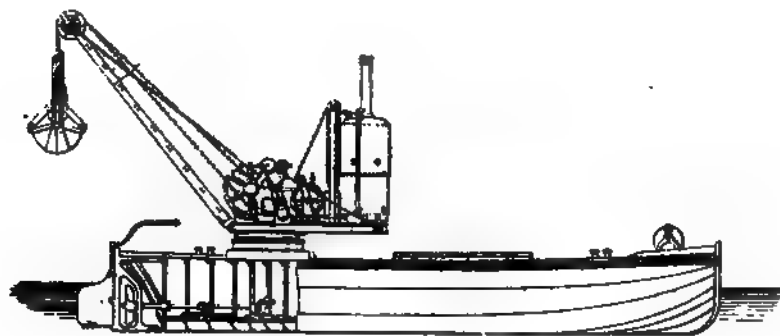


Fig. 646. Crane and Grab mounted on a Barge.

There are now, however, many different designs of grabs in use working with two, three, or four chains or ropes, as well as others operated by a single chain only.

These appliances are used for discharging coal and other heavy material, as well as for dredging purposes. Generally speaking, the mechanical details are identical,

the cranes only differing in the way in which they are mounted according to the purposes they have to serve. Thus they may either be fixed on quay walls, mounted on wheels, or installed in suitable barges, the latter being more often used for dredging purposes, as shown in Fig. 646.

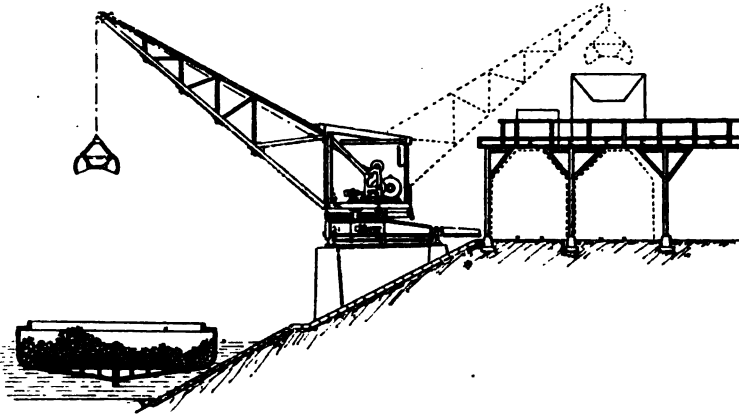


Fig. 647. Crane and Grab for Unloading Purposes.

APPROXIMATE QUANTITY OF MATERIAL ONE MAN CAN RAISE
WITH A PRIESTMAN GRAB PER DAY OF TEN HOURS FROM
AN AVERAGE DEPTH OF 20 FEET.

Capacity of Bucket or Grab, in Cwts.	Grain, in Quarters.	Small Coal, Shingle, etc., in Tons.	Coke, in Tons.
3	...	...	...
5	...	...	...
10	1,200	200	125
20	2,400	400	200
30	3,200	550	275
40	4,000	700	350

Fig. 647 illustrates a very usual method of using grabs for unloading barges and depositing the material in railway trucks.

The Hunt Grab is another example of a two-chain type, and is illustrated in Fig. 648.

The principal difference between this and the Priestman grab is that whereas in the former the jaws are swivelled to the centre of the grab and closed from the outside, in the latter the jaws are swivelled at the haunches (Hone's patent) to an A-shaped frame, and are drawn together at the centre, which effects a rather more powerful closing action. Moreover, as the jaws open wider, they can take in a larger quantity of material at each lift. One chain is attached to the drum A on spindle B, and the other chain is fixed to the frame. If the first chain be released and the second chain held tight, the grab opens. The short chains are not attached to a second

spindle as in the previous grab, but to the top of the framework, as in the latest Priestman grab.

In two-chain grabs the second cable or chain is not always wound on a second drum of the crane, but is often held by an independent drum and brake in connection with a balance weight, a method devised by Messrs Priestman, which acts as follows:—

The cable which opens the grab is attached at the crane end to a drum which is loose on a spindle. Cast together with this drum is a second one of smaller diameter from which a second cable leads over a guide pulley to a balance weight. This weight is held in position between two guides, generally behind the crane house, and is fitted with a safety catch to prevent it from falling in case of the rope breaking. The loose drum is ordinarily provided with a band brake manipulated by a special locking lever. As the drum is thus held fast by the brake and the main cable lowered, the jaws of the grab are opened. By a slight modification, this apparatus may be made to act automatically, in which case the spindle is made to revolve by means of a chain connected

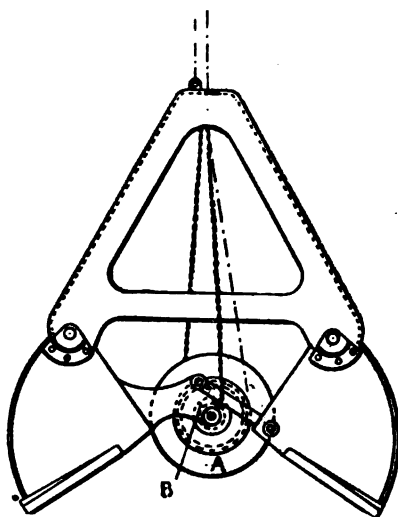


Fig. 648. Hunt Two-Chain Grab.

to the main drum of the crane. On the spindle a thread is cut to which a nut is fitted, the latter being of an easy fit and so weighted as to prevent it from revolving with the

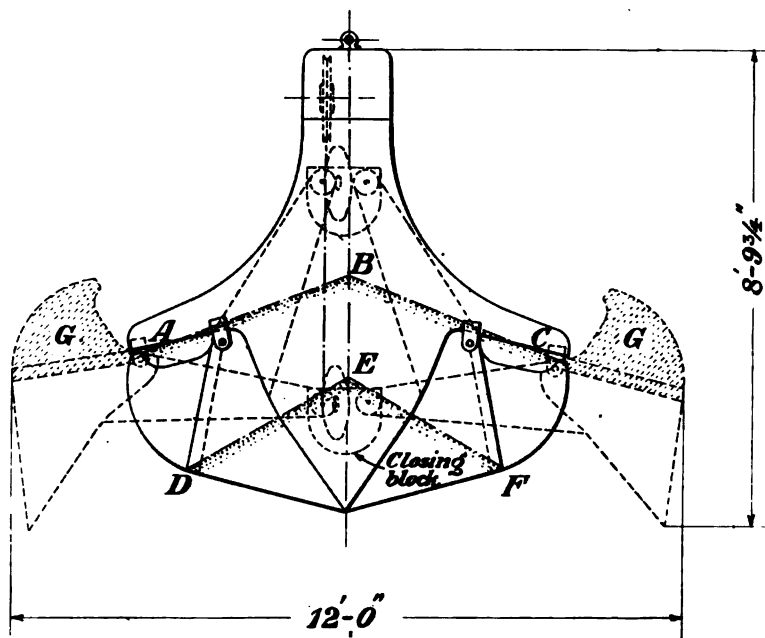


Fig. 649. Elevation of the Brown Hoisting Machinery Co.'s Two-Rope Grab Bucket.
(The width of the Grab is 5 ft.)

spindle. Instead of that, it passes along the thread till a point is reached which forms an obstruction to its further progress, when it has to revolve with the spindle, which movement is used to throw the apparatus out of gear.

Two-Rope Grab of the Brown Hoisting Machinery Co.—The grab, which is illustrated in Fig. 649, has a capacity of 2 tons, and is used for unloading coal as well as for handling ore; it is also built for larger and smaller capacities. The one here illustrated, when used on coal, will handle 84 cub. ft., and when used on iron ore about 35 cub. ft., which would mean approximately 2 tons of either material.

When handling coal, the pile taken by the grab is indicated by the line *A B C*. When handling ore the attachments *G G* are removed, leaving the ends of the jaws open; the grab can thus only take a pile of ore as indicated by the line *D E F*.

This form of grab works satisfactorily with coal of all sizes, and it is specially claimed for it that it will handle very large pieces. It also works successfully with nearly all kinds of iron ore, with perhaps the exception of some of the lumpiest Swedish ores. It has, however, been proved capable of handling Spanish ores satisfactorily. The illustration gives over-all dimensions of the grab when open.

The accompanying drawing, Fig. 650, shows a cross section through the grab when closed, with dotted lines indicating the path of its jaws from an open to a closed position. To the housing of the grab is fastened (to obtain the compound movement) a rail or track *T*, upon which are hung sliding blocks or pieces *bb*, pivotally connected with the forward portion of the jaws *JJ*, which are composed of two parallel sides *pp*, joined at their outer ends by cutting blades *DD* which are set at a sharp outward angle. The parallel sides *pp*, however, are cut away and recede upwardly from the lower or scraping edges toward their upper ends, so that when the jaws *JJ* are brought together and the grab thereby closed, a small portion of the sides will remain open.

In the form shown in the drawings, the front and rear of the jaws are preferably unenclosed, and extend out beyond the housing when opened to their outward limit. The sides *pp* are stiffened by diagonal ties *ee*.

Centrally within the housing of the grab is the block *c*, carrying a series of sheaves *m*, mounted upon a common journal or shaft *j*. The block is provided with trunnions which fit into vertical guide grooves on the inside of the casing. The lower ends of these grooves are closed so that the descent of the trunnions is limited.



Fig. 650. Cross Section through Brown Grab.

At the upper end of the framing is a second block *ε*, containing another series of sheaves *m*, which in the construction illustrated are one less in number than the sheaves of the lower block or head *c*. The sheaves in the blocks *c* and *ε* are set at an oblique angle to the framing, so that the sheaves and off-running portion of the operating rope shall come on the centre line of the top of the grab. Rope guides or eyes *mn* are provided on opposite sides of the block *ε*, with centres corresponding to the centre lines of the grab. Hinged to the block *ε* is the hoisting block *g*, having rope guides or eyes *m'n'* at either side, being just opposite the guides or eyes *mn* on the block *ε*. *o* is the rope whereby the grab is closed or allowed to open; it passes downward through the eyes *m'* and *n'*, around the sheave in the upper block *c*, thence upward round a corresponding sheave in the upper block *ε*, down around the next adjacent sheave in the block *c*, and so on around any remaining sheaves, when the outgoing portion of the rope is carried up through the eyes *n* and *n'* to the hoisting mechanism. *r* is the hoisting rope, which is reeved round the hoist block *g*, and connected with the winch in the usual manner.

The grab is operated by lowering it on to the material by paying out both the hoisting and the operating ropes. When in proximity to the material the hoisting rope is held taut and the operating rope *o* is slackened. The block *c* being thus freed, will, by reason of its weight, descend within the framing or the housing of the grab, being guided vertically by the trunnion grooves, at the same time carrying with it and depressing the pivoted inner ends of the jaws *JJ*. It is evident that by this movement the said jaws being pivotally connected near their outer ends to the sliding blocks or pieces *b* and *b'*, mounted on the guides *τ*, said blocks will be forced outwardly along the track *τ*, and carry with them the outer ends of the jaws *JJ*, and the grab will thereby be opened. The contour of the track *τ* is such that in connection with the vertical movement of the head *c*, the blades *DD* in their course in opening and closing will be constrained to describe any desired curve or course within the grab's limits—such, for instance, as that indicated by the dotted lines in Fig. 650. In practice, particularly where material is to be taken from flat surfaces or from against the sides of a bin or barge, the path of the blade-like part *D* should at the initial movement of closing descend with a sharp curvature that diminishes as the jaws approach each other, whereby the material is first penetrated by the jaws to some depth to ensure a purchase and load, and is then scraped together within the jaws of the grab.

As indicated by the drawings, the downwardly projecting pieces *s'* serve to prevent the escape of material at the sides where the jaws are closed, and by leaving the rear of said jaws unenclosed any surplus load above the capacity of the grab will be forced out without in any way crowding within the grab, and thereby interfering with its proper working.

Both illustrations show the Brown grab with guide bars *τ* (which are connected to the movable fulcrums of the jaws) in a straight line. These guide bars can, however, be made in any other shape, in which case the curve described by the cutting edges of the jaws will differ correspondingly.

Hone's Single-Chain Grab.—The first successful single-chain grab was undoubtedly that on Hone's patent, originally manufactured by the Thames Iron Works and Shipbuilding Co., Ltd., and now by Priestman Bros., Ltd., Hull. Although of comparatively recent origin, this grab has undergone many changes in design.

The original patent, which was obtained by George Hone in 1882, consisted essentially of an oblong bucket fitted with a shifting bail, which was worked by a spring manipulated by an attendant on the crane by means of a string. The bucket descended

in a vertical position, the line was then drawn taut, when the spring released the bail, and, changing its position, locked the apparatus, then by a circular motion the load was filled and raised.

The patent for the Hone grab as now manufactured was granted in 1894. It is illustrated in Fig. 651, and apart from being the first single-chain grab, it was the first which pivoted the jaws from the haunches.

The working parts of the grab consist of a rising and falling sheave block *A* (called the sliding block), having two vertical loose sheaves mounted in it, and arranged to rise and fall within a guide of four vertical angle steels of the framework; a single vertical loose sheave *B*, mounted on a circular horizontal plate, this plate forming a cap to the four vertical angle steel guides mentioned above, and having suitable holes in the plate for passing the crane chain through; a crosshead *C*, situated below the sliding block, and also free to rise and fall in the same four angle steel guides, has a fixed vertical central pin with a semicircular notch across it. The top end of the pin is so arranged as to enter the vertical hole in the lower end of the sliding block, and the bottom extension of this pin is formed into lugs, to which the closing rods *D D* connecting the jaws are attached, so that when the crosshead is lifted in the guides the jaws are closed. This horizontal locking pin fits into a horizontal hole through, and at the bottom of, the sliding block, in such a position that half its diameter passes through the notch in the vertical pin on the crosshead. The locking pin has also a notch in it, in such a position that when the notches come opposite each other the crosshead pin is free to disengage from the sliding blocks. The releasing lever *E* is "swung free" on one end of the locking pin, and having a balance weight *F* at its back short end, the long end at the other side of its centre is free to rise. A vertical stop and balance weight is fixed to the locking pin, and is of sufficient weight to keep the pin always locked. To this plate two stop pins are fixed, and the long end of the releasing lever *E* is always bearing against the top one in consequence of its balance weight. The second stop pin fitted on the same plate lower down is only provided for safety. A ring *G* is hung from the jib-head, of such a diameter as to allow the vertical framework to enter it easily, but not large enough to allow the long end of the releasing lever *E* to pass without being either depressed or raised. A vertical oil-checking cylinder *H* is fixed at its upper end to the top horizontal plate of framework, and its piston rod passes through a gland at the bottom end of its cylinder, a suitable vertical clearing hole in the sliding block being provided, and is then attached to the crosshead *C*.

The grab is worked as follows:—

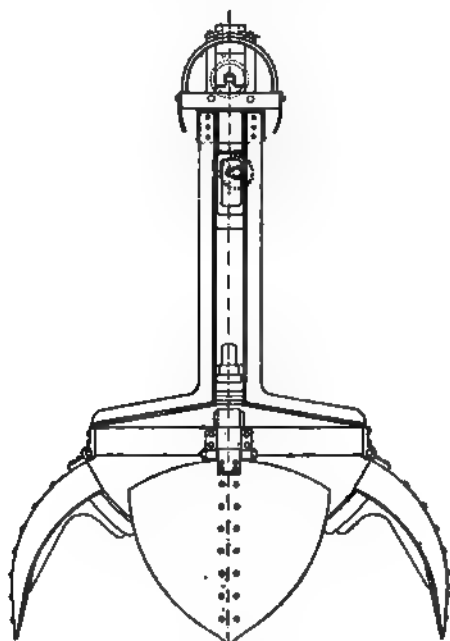
The ring *G* is hung from the jib-head at any required height which suits the point of discharge.

To rig the chain, the free end of the crane chain is passed down through the central hole of the top plate, then under one of the sheaves in the sliding block below, up through second hole in top plate, under the second sheave in sliding block, and up again to the under side of top plate, to which it is attached by a bolt and lug, no special link

Fig. 651. Hone Grab.

being required. The operation of rigging the chain in the grab is exactly similar to reeving a double and single chain block, and can be effected by any unskilled labourer.

As soon as the grab has been lowered on to the coal (the crosshead *c* being at the bottom of the guides, and the sliding block *A* at the top of the guides) the sliding block will, by its own weight, and the overhaul of the chain, run down the guides until the crosshead pin enters the hole in the bottom of the sliding block. This also lifts the balance weights and the machine becomes locked. The grab is now ready to dig, and on starting the crane to "heave up," the sliding block and crossheads are pulled up between the guides at a leverage of 4 to 1, until the grab is completely closed. The load is then lifted to the



Figs. 652 and 653. Hone Grab with Four Jaws (sometimes called an "Orange-Peel" Grab).

required height, and the top portion of the grab must also be so far through the ring *c* that the long end of the releasing lever *E* has been depressed by the ring, and having passed through it, has swung back again against the top pin. On lowering the grab, the releasing lever *E* comes in contact with the top edge of releasing ring *G*, thus lifting the stop plate and turning the locking pin until the two notches come opposite each other, when the crosshead, being released, falls from the sliding block, and the jaws and closing rods drop with it. The piston rod gently descends at the same time, thus preventing shock to the machine, or the scattering of the material. On lowering clear of the ring, the releasing lever and locking pin reassume their positions by means of their balance weights, and the grab is once more ready to be lowered into the barge.

Figs. 652 and 653 show the same grab made with four jaws instead of two. This form is used chiefly for excavations under water and for extra stiff clay.

The following table gives dimensions, weights, and capacities of the Hone grab :—

Size.	Dimensions of Grab when Closed.	Approximate Weight of Grab.	Capacity, in Cubic Feet.	Rate of Discharge in Tons of Coal per Hour with Ordinary Steam Crane at about 40 ft. lift.
No. 1	3 6 by 3 6	13	15	20
" 2	4 0 " 3 6	14	18	24
" 3	4 0 " 4 0	17	23	29
" 4	4 0 " 4 6	21	30	37
" 5	5 0 " 4 0	22	35	41
" 6	5 0 " 4 6	24	39	45
" 7	5 0 " 5 0	29	44	50
" 8	6 0 " 6 0	48	78	72

At the Beckton Station of the Gas Light and Coke Co., the collier "Eleanor," having a cargo of 2,750 tons of coal, was discharged in sixteen and a half hours by three No. 7 Hone grabs, manipulated by hydraulic cranes.

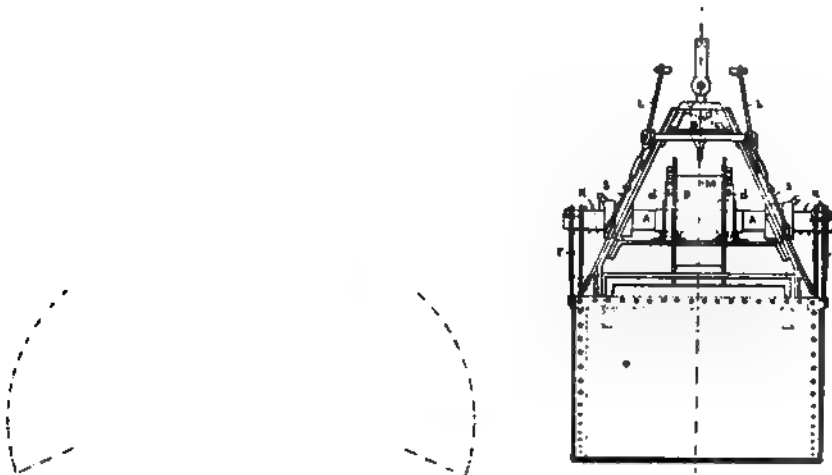


Fig. 654. Bleichert Grab built on the Hone Principle.

A Continental modification of the "Hone" grab (Bleichert's) is illustrated in Fig. 654. The action is as follows :—

In the closed position the two short outer chains *KK* are wound round the spindle *A*, whilst the inner chain *M* hangs loosely in the interior, or lies on the top of the material contained in the grab. The movable portion *B* is held in position by pawl *C*. The drum is held by the two pawls *dd* and the ratchet segments which form part of the drum. In order to discharge the load the two levers *LL* are made to touch an obstruction which is suspended from the head of the crane, and is adjustable up or down. As this is in a fixed position, when the grab is being lifted the levers *LL* are forcing down, by means of two short chains, the pawls *dd*. The drum *D*, which is fixed to the spindle *A*, is compelled to revolve through the weight of the grab and its load, so that the two small chains *KK* unwind from the spindle *A*, whilst the hitherto slack chain *M* winds itself on to the drum *D* during the process of opening. As soon as the apparatus has thus been

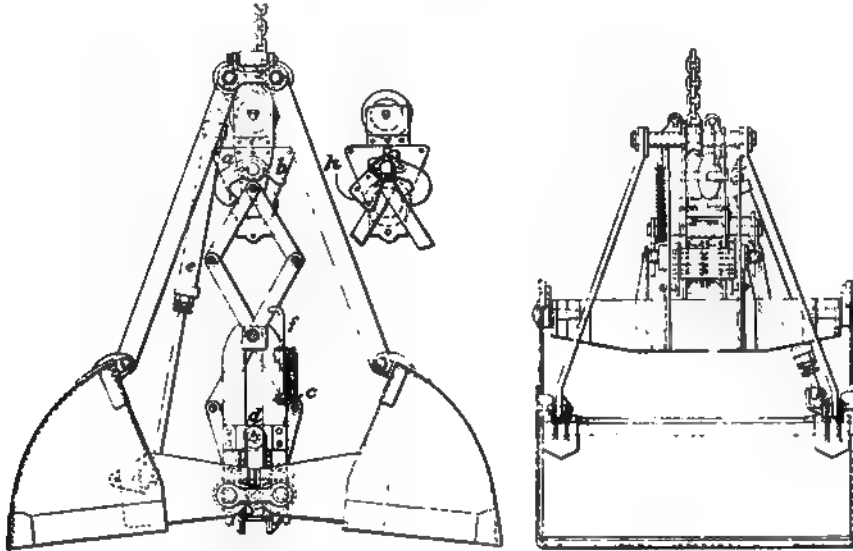
discharged the main chain begins to lower, when the levers LL, being released from the obstruction, are pulled back into their original position by the springs SS, while the pawls dd hold the drum D in its position, and thus keep the jaws open as the grab plunges into the material to be elevated. If the rope or chain be now further lowered, the part B sinks by its own weight into the opening in the top of the framework, and in so doing the pawl C is pushed to one side and held in that position by another small catch. The hoist chain is now pulled up by the crane, B is now no longer held in position, and as it is pulled out of the framework, pulls with it the chain M and unwinds it from the drum D. The revolutions of the drum, and with it of the spindle A, wind up the two small chains KK, and pull up the levers TT, thus closing the jaws. As soon as the grab is thus closed, the chain is lowered once more for a foot or so. B re-enters its former position, and is now again held in place by the pawl C, which has in the meantime been released. As B re-enters the frame, the chain M is released and lies loosely on top of the load as the drum is now fixed, when the grab is ready to be lifted and swung into position for delivery.

The Barnard Grab.—The latest development of the single-chain grab is the invention of Mr D. J. Barnard, and is manufactured by Messrs William Goodacre & Sons, Ltd., of London. Such a grab, in its simplest form, is illustrated in Figs. 655, 656, 657, and 658.

The grab, as shown in Fig. 655, is lowered by the crane on to the material to be handled, and as it works on the block and tackle principle, the chain or rope is still further paid out after the grab has come to rest, so that the sheave block *a* will now descend on its own weight, when it assumes the position shown in Fig. 656. An important part of this grab is the simple attachment to the lower sheave block *a*, consisting of a loose fitting bolt or pin, to which is keyed at one end a hook or clutch *b*, which is developed into a spigot, standing at an angle of about 90° to the hook; while at the other end there is another clutch *b*, but instead of a spigot, there is a counterweight *h* (see small details to Figs. 655 and 658). We thus see that the natural tendency of this small device is to assume its normal position, as shown in Fig. 655. As soon, however, as the grab has come to rest on the material and the lower sheave block is descending by the paying out of the rope, the spigot on the clutch *b* comes in contact with a spring operated plate *c*, and as the weight of the block *a* easily overcomes the resistance of the spring, the clutches *b* are pushed under the pin *d* at the moment when the block *a* has reached its lowest position, as shown in Fig. 656, when the grab is ready to close and take its fill. This grab is hinged at the haunches, as it is termed, and the position in which the jaws are shown, both in Figs. 655 and 656, is one which they would naturally assume, being suspended above their centre of gravity. In order, then, to close this grab, the hinged central portion must be lifted up, and this is only possible by coupling that portion to the lower block *a*. This is accomplished as soon as the clutches or hooks *b* embrace the pin *d*. Thus the hauling in of the rope closes the grab, and just prior to its final closing up, the upper end of the spring-rod *f* comes in contact with a projection carried by the top sheave plates.

In order to reopen the grab for the delivery of the load, it is necessary to rest it for a moment upon a grating or on the heap of material already lifted, while the hoisting rope is slackened a few inches, which will suffice for the small balance weight *h* to assert itself, and cause the clutches to assume their natural position, free from pin *d*. On again reversing the crane and hauling in rope, the grab will open and discharge its load very gently. It has already been pointed out that the weight of the jaws of this grab will naturally keep it in an open position, the more so on account of the load; in order, there-

fore, that the opening should not be unnecessarily violent, an oil dash-pot *c* (see Figs. 655 and 656) has been provided, which retards the opening and keeps it well under control. This action is so precise, that the grab on its return journey, when it has left its load



Figs. 655 and 656.

Figs. 657 and 658.

The Barnard Grab in Four Positions.

behind, is still opening wider, and is not fully opened until it reaches its field of action again.

An important point is light self-weight for a given capacity: thus, a grab having a capacity of 1 ton of coal weighs also about 1 ton; it is thus possible to install one of

these grabs on an old type crane where the margin of power is small, and by the substitution of a chain by a wire rope the dead weight can be still further reduced, as this grab is equally suitable for a chain or rope.

Pneumatic Grab.—A grab, operated by compressed air, is built by the W. H. Beard Dredging Co., of New York. The jaws are opened and closed by means of air pressure. The contention of the inventor is that the grab, when embedded in the material to be raised, should be closed without pulling a chain or rope, as this might have a tendency to loosen the hold of the jaws upon the material, with the effect of diminishing the load to be raised.

From the chain of the grab (Fig. 659) is suspended a frame A, which carries the air cylinder B and the crosshead guide which supports levers CC. Although this grab has only one chain its manipulation is somewhat complicated.

Fig. 659. Pneumatic Grab of the Beard Dredging Co.

There are two air-pipes to be raised and lowered with the grab, one to connect the upper and one to connect the lower end of the cylinder with the compressed air vessel. This is effected in the following manner: A drum is fixed to the jib-head of the crane, and to its hollow spindle the two air-pipes are attached by means of stuffing boxes on either end. The two flexible air-pipes leading to the grab are rolled upon the drum, one end of each being connected with the main pipe through the stuffing boxes. As the grab descends, the pipes unroll from the drum and cause the latter to revolve, thus winding a rope (on the end of which is a balance weight) upon the drum, so that as soon as the grab ascends again the weight on the rope turns the drum in an opposite direction and winds the two pipes up again, so that they are always taut no matter in what position the grab may be. To manipulate the grab a three-way valve is used, two of the exits communicating with the upper and lower ends of the cylinder, and the other with the compressed air vessel.

Hydraulic Grab.—This (Fig. 660) is similar to the last mentioned, but is operated by hydraulic power. The arrangement of the jaws and their guides is similar to the Priestman principle.

The casting upon which the jaws are hinged is connected to the cylinder by powerful vertical rods. The lower large piston closes the jaws, whilst the upper is for the purpose of withdrawing the former, and thus opening the jaws. Both pistons are connected together by rods, and the stuffing boxes are easily accessible. This apparatus is said to be satisfactorily at work in the United States.

Electrically Driven Grab.—Grabs have lately been fitted with electro-motors, so

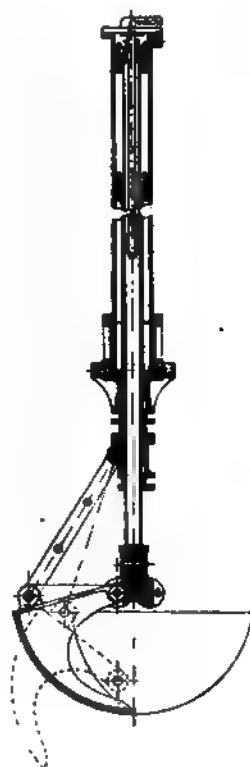


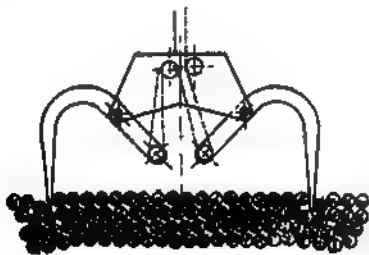
Fig. 660. Hydraulic Grab.

that all the work the crane has to perform is to lower the grab on to the material to be raised, in an open condition, when the current is switched on to the motor which closes the grab, and similarly opens it after it has been conveyed to its destination. As the capacity of the grab depends to some extent upon its own weight, it is obvious that a grab so fitted will have an increased weight, which adds to its efficiency. The rope cannot lessen the hold of such a grab on the material as it does not come into action until the grab is closed. This seems an ideal solution, but the construction presents several difficulties, one of which is the reduction of speed from the fast running motor to the very slow closing action of the grab; the gearing which transmits the power is, therefore, necessarily complex and heavy. This appliance is especially suitable where a heavy grab is necessary. Figs. 661 and 662 show an example of the application of the principle to a Continental grab built by the Augsburg-Nürnberg A. G. This is applicable for heavy ores, and the closing power is exceptionally great. This grab has been used for handling Thomas phosphates, which is one of the most difficult materials to deal with, and for which a heavy grab is necessary. The weight of the grab alone is 6 tons, and it has a capacity of approximately 2 cub. yds.; the grab actually lifted in one operation over 3 tons of this material.

The electro-motor is of 15 H.P., and the transmission of power from this to the jaws is effected by worm and worm wheel, two pairs of spur wheels, and a chain drive. The last three examples are here given merely with a view to completeness.



Figs. 661 and 662. Grab Manipulated by Electric Motor.



Figs. 663 and 664. Grab for Timber such as Mine Props.

Electrical grabs of more promising design are now being developed in this country and also in America.

Appliances Similar in Principle to Grabs.—These take the form of huge tongs and are frequently used in the iron and steel industry for handling large single loads.

An interesting example of a similar appliance for unloading short lengths of timber out of barges has been described by Professor Buhle.¹ The timber handled is used for manufacturing wood pulp, and the pieces, which are very similar to mining props, are about 6 ft. long and do not exceed 1 ft. in diameter. Figs. 663 and 664 show this

¹ *Zeitschrift des Vereins deutscher Ingenieure*, 15th May 1909.

appliance open and closed. The action very much resembles that of a grab, with the difference that the appliance must not be opened until the timber has been lowered on to the ground or on to the timbers already accumulated, in order not to disarrange them. The weight of the appliance is close upon $1\frac{3}{4}$ tons and it will handle on an average $1\frac{1}{4}$ tons of timber at each grip, which is equal to about 3 cub. yds. It is used in connection with a man telfer, and installed on a long bridge crane which spans the store yard, and makes thirty to thirty-five journeys per hour.

The Lifting Magnet.—Although this latest and most useful appliance cannot, strictly speaking, be called a grab, it so nearly fulfils the same essential functions that it must be included in this chapter.

The earliest attempts to utilise on a large scale the affinity of the magnet for iron and steel are said to have been made at the Otis Works in Germany, as early as 1889, for lifting and conveying blooms, and a little later by the Illinois Steel Co. in the United States for iron plates. The pioneers of a really serviceable lifting magnet of commercial value were S. T. Wellman, who in 1895 used them for handling plates and slabs, and D. B. Clark, the electrical engineer of the South Works of the Illinois Steel Co., who subsequently improved the design.

¹The manufacture of lifting magnets of both the Wellman and Clark types was taken up by the Electric Controller and Manufacturing Co. (then the Electric Controller Supply Co.) about 1898. A special magnet testing machine was designed and installed and much valuable data secured bearing on the design of the lifting magnet.

Many magnets of the Clark type have been manufactured and sold and have given excellent results in the handling of smooth homogeneous material, such as plates, blooms, and slabs; these magnets were, however, useless for handling rough and detached material, such as pig iron, crop ends, and scrap. A magnet which would readily lift a steel ingot weighing 10,000 lb. would not lift a single pig of iron weighing 100 lb. Many were the disappointments encountered in solving the problem of overcoming the electrical and mechanical difficulties of a principle, which was practically solved when the electro-magnet was discovered in 1820 by Ampère. Success came slowly, but that it has been attained is proved by the fact that the lifting magnet is to-day the greatest labour-saving device which the progress of electric engineering has achieved.

The first commercially successful lifting magnet for handling pig-iron scrap and miscellaneous magnetic material was placed on the market in March 1905. This was built in two sizes known as No. 1 and No. 2 type S. Magnet. Hundreds of these magnets have since been placed in the service of the iron and steel industry, and it may be said that they possess lasting efficiency; and the price, size, current consumption, and lifting capacity are in reasonable proportion to their own weight. They have, in fact, become satisfactory and reliable tools. The makers, however, have not been content to rest upon the satisfactory results thus far obtained with the type S. magnets, but have been constantly at work on improvements both in the direction of dependability and in increased efficiency in the handling of material.

Unquestionably a successful lifting magnet must withstand more severe abuse and rough handling than any other type of electrical apparatus. In operation they are suspended from the hook of a crane, frequently not equipped with a lowering brake, so that it may be dropped at a high speed upon the material to be lifted; then it is swung

¹ Compiled from articles, "Recent Improvements in Lifting Magnets," in the *Industrial Magazine* of December 1908; and "All About Lifting Magnets," in Cassier's "Engineering and Industrial Management," 11th September 1919.

when in use against cars, boxes, piles of pig iron, etc., and must be capable of withstanding the blows and shocks which result. It must operate under all weather conditions, and its insulation must withstand a voltage much higher than line voltage due to the inductive kick which occurs when the circuit of the magnet is opened. Its winding must not be injured by the heat which is generated within it, and preferably should also withstand external heat when the magnet is called upon to handle hot material.

The accompanying illustration (Fig. 665) is a section through a typical S. A. magnet, and shows the arrangement of the parts, which by experience have been found to meet the severe and exacting requirements of the service. A is an annular casting of special electrical steel, forming the body or framework of the magnet; it is heavily ribbed on both the upper surface and the periphery, thus providing cooling surfaces. They are so disposed as to stiffen the magnet case, and at the same time to add to the cross section of the magnetic surface. To this frame rings for supporting the magnet on the crane are also secured. B is the core of the magnet which is surrounded by the winding C. This winding is composed of a series of coils, each wound with a conductor in the form of a copper ribbon or strap, the turns of which are insulated with asbestos ribbon. Neighbouring coils are mechanically separated and electrically insulated by non-combustible insulating discs D. The coils are wound upon a heavy brass form E, which resembles a spool with one head removed. This form serves to support the coils during the process of winding, and ensures their being of uniform and perfect shape, since there is no danger of springing

Fig. 665. Section through Lifting Magnet.

or otherwise distorting the winding. After the last or uppermost coil is wound and the outer disc of insulation in place, the entire winding is rigidly clamped to the forms by means of radial straps F, which are bolted and locked in place, thus making the winding and the brass form which carries it a rigid unit. The completed winding is then dried in a heated chamber under a vacuum, and when the initial drying process is completed, the winding is impregnated with a plastic insulating compound—first under influence of a vacuum and then under air pressure, and finally is again dried under a vacuum. This results in a winding not only fireproof, but what is of still greater importance it is thoroughly waterproof. The completed winding is then placed in the magnet case.

It will be noted that the form E is provided with an outer flange e_1 , and an inner flange e_2 , in addition to the central upwardly-extending flange e_3 , which centrally supports the winding. The inner and outer flanges are carefully finished, and engage with finished surfaces on the inner and outer pole faces of the magnet case, thus completely sealing the lower face of the winding chamber, a water-tight joint being ensured by clamping the flanges in place with screws e_4 , e_4 , spaced 4 in. apart entirely around the flanges e_1 and e_2 . Since the winding is clamped to the form E by the radial clamp F, and the form E is clamped in the magnet case as already mentioned, it will be readily seen that the winding is rigidly held against displacement. With the winding thus assembled in the magnet case, the lower face of the coil form E is covered by a heavy annular plate G of (non-magnetic) manganese steel, which in turn is held in place

by pole shoes *H* and *I*, bolted respectively to the inner and outer poles of the magnet case. Both the pole shoes are provided with shoulders, which protect the clamping bolts from sheering strains. At the heads of the outer pole clamping bolts *J* are located between adjacent ribs on the outer surface of the magnet case, where they are protected from abrasion. In the sectional view it will be noticed that the practically non-magnetic manganese steel plate *G* carries raised shoulders around its inner and outer peripheries by means of which the plate is made to seat against the magnet poles, and an air space or cushion is left under the winding at *g*. This results in the shocks taken by the outer plate *G* being transmitted directly to the magnet frame, instead of being taken by the windings as would necessarily be the case if a plain bottom plate were used.

The pole shoes are so disposed with respect to the outer plate *G* that none of the clamping surfaces can become battered over, and therefore the plate *G* as well as the whole wearing surface may always be readily renewed.

The terminal cavity is surrounded by a ridge *K K* cast integral with the magnet case, and of a thickness to make it as strong as the magnet case itself. The terminal cavity is closed with a heavy steel cover *L*, which seats against a gasket to form a water-tight joint, and is firmly bolted in place, the heads of the bolts being protected from abrasion by the ridge of the terminal cavity.

All the terminal parts are thus enclosed in a waterproof box of steel, the terminals themselves being of the plug type, which permits of quick attachment and detachment of the service wires. The female members *M* of the terminal are enclosed in an insulated tube, so that a ground or short circuit cannot

Inner Pole Shoe.

Fig. 666. Cutler-Hammer Lifting Magnet.

result even if the service wires are left hanging from the crane with the current on. The insulating tubes are each encased in a steel tube to prevent abrasion of the insulation, and these steel tubes fit closely into babbited openings *N* in a side of the terminal chamber. The male member *P* of the plug connectors is mounted upon a heavy plate *R* of fireproof insulating material, which closes the entrance to the winding chamber and is seated upon a gasket to effect a water-tight joint. The plugs proper are separable from the terminals by removing the nuts which hold them in place. The plugs, and also the plate *R*, may therefore be removed without throwing any strain on the connections to the winding; the connections consist of loops of very flexible copper ribbon, these loops being stowed away in the box-like ends of the terminal studs. This construction permits of great flexibility, and at the same time makes it impossible for the flexible leads which connect the two ends of the magnet windings to come accidentally into contact. These features show how carefully the design of type S. A. magnets has been considered and worked out from the mechanical and electrical standpoint.

Fig. 666 shows a lifting magnet of the Cutler-Hammer Co., Milwaukee, U.S.A., in which the terminal box is separate, and not cast together with the body of the magnet, and the whole apparatus is held together by through bolts.

The following figures have been obtained, during the test of a 50-in. magnet of this type, at the plant of the Youngstown Sheet and Tube Co.:—

Total weight of pig iron unloaded from steel gondola	-	109,350 lb.
Weight of average lift (including small lifts when cleaning up the car)	-	785 "
Trips required to empty gondola	-	139
Current on magnet	-	1 hr. 15 min.
Current off magnet	-	50 "
Time consumed in unloading gondola	-	2 hrs. 5 "
Current required to energise magnet	-	30 amperes at 220 volts.

From the foregoing figures the cost of operation is easily calculated, assuming cost of current to be $1\frac{1}{2}$ d. per kilowatt hour; 30 amperes at 220 volts correspond to a power consumption of 6,600 watts which was required for one hour and fifteen minutes; this gives a total power consumption of 8.25 kw. hrs., which at $1\frac{1}{2}$ d. per kilowatt hour gives a total of a little more than one shilling for the cost of current required for energising the magnet during the period of unloading pig iron.

The following table gives the capacity on different materials, for the four sizes of lifting magnets made by the Cutler-Hammer Co. :—

Material Lifted.	Diameter of Magnet.			
	36 In.	42 In.	52 In.	60 In.
Pig iron from casting machines	Lb. 800	Lb. 1,170	Lb. 1,980	Lb. 2,340
Pig iron cast in sand	720	1,100	1,800	2,160
Boiler plate scrap	630	1,080	1,440	...
Scrap wire	450	540	720	900
Rail cuttings and crops	720	1,200	1,620	...
Skull cracker	10,800	18,000	18,000	22,600
Weight of magnet	1,630	3,000	4,700	6,800

Magnets of the Witton-Kramer Electric Tool and Hoist Co., of Witton, Birmingham, one of which is shown in Fig. 667, are no longer impregnated, but the coil is clamped into position in the shell by mechanical means, consisting of asbestos packing pieces and manganese steel clamps, an air space being left between the shell and the coil to allow of expansion. The latest magnets contain no combustible substance and can be used in perfect safety for handling material of a temperature up to 6,000° C. They differ from those previously described particularly in that the windings are treated similarly to the type S.A. magnet with the exception that they are immersed in a boiling asphalt compound, and the coils are kept under great pressure in this liquid at a temperature of approximately 200° Fahr. The shield which protects the coil is either of non-magnetic manganese steel or of an extra hard phosphor bronze, and the pole shoes are generally bolted to the casing, but in some instances they are soldered.

The controllers for these magnets are of the drum type, and in some cases oil-immersed. Non-inductive resistances are employed to take up the induction of the coil when breaking the circuit.

The wiring necessary for operating lifting magnets consists of a twin cable, which is led over a system of pulleys provided with a counterweight to keep the cable taut. In the case of jib cranes this cable is connected to the supply in the crane cabin, but for travelling cranes it is usual to install two trolley wires alongside the bridge and to provide special collectors to collect the current. A spring drum may sometimes be employed upon which the cable is wound and unwound as the crane is in use.

The method of working a magnet crane is similar to that of any electric crane, with the addition only of an extra controller for exciting the magnet when lowered on to the material to be lifted, and for releasing the load at the destination.

The holding capacity of magnets depends largely on the nature of the material which is to be handled, such as the magnetic quality of the load, the temperature of the material (*which should not be above black heat*), the shape of the material, and the size of the pieces. For general guidance it may be assumed that a magnet is capable of lifting a solid piece of steel with machined surface of not less diameter than the magnet itself, having approximately a weight of fifteen times that of magnets under 2 ft., or eight to twelve times the weight of magnets from 2 to 3 ft. in diameter, and five to six times the weight of magnets from 3 to 5 ft. diameter.

For such materials as sand-cast pigs, or heavy scrap iron, the lifting capacity decreases considerably, as the material does not conform to the surface of the magnet. When handling iron or steel plates the load depends on their size; sometimes up to six plates

Fig. 667. The Witton-Kramer Magnet.

deep can be lifted according to the thickness and weight of the plates and the type of magnet.

During the times the plates are suspended on the magnet it is possible, by passing the current through resistances, to drop one plate at a time and still hold the remainder.

Lifting magnets are made round, oval, square, or oblong, and the surface of the magnet should also have a shape as near as possible to that of the objects generally lifted by it; for instance, if used for lifting iron pipes the lifting surface of the magnet should be hollowed out to fit, and by the same rule if used for a "skull cracker" the surface should be concave. Where long or bulky objects have to be lifted, a number of smaller magnets are suspended from girders or frames in order to cover a larger surface of the objects being dealt with.

Lifting magnets are not only used for handling iron and steel in all its forms in the ordinary way of manufacture and shipment, as well as in engineering works, but they are also great labour-saving appliances for breaking up cast-iron scrap, as the same magnet will not only handle it before and after it is broken, but will also lift and drop the "skull

cracker" with which the scrap is broken up. They are also very useful for handling iron ore provided it contains not less than 60 per cent. of iron.

Lifting magnets are only constructed for direct current and are best driven from the mains without the intervention of cut-outs. In some cases it is advisable to install an additional accumulator battery to work in parallel with the dynamo, so that should the latter break down, the accumulator will hold the load.

An up-to-date lifting magnet is no more likely to fail and drop its load than is a hoist cable or chain.

One of the greatest economies effected in raising loads with lifting magnets, as compared with ordinary cranes, is the saving of the time wasted in slinging the material



Fig. 668. Hulett Unloader as used by the Pennsylvania Railroad Co. at Cleveland, U.S.A.

(The dimensions are in metres.)

with chains prior to its being raised, and the removal of the chains at the destination. Another is that practically all ground men become unnecessary.

The Hulett Unloader¹ is the invention of H. H. Hulett, engineer to the Wellman-Seaver-Morgan Co., of Cleveland, Ohio. This wonderful and complex machine, which must be classified under grabs, though it differs widely from them; is unsurpassed in handling capacity and is built for the specific purpose of unloading ore and coal ships which are specially built for this traffic. The first machine was installed at the iron ore docks of the Pittsburg and Conneaut Dock Co., of Conneaut, Ohio, in 1898. In these unloaders the clamshell, of 15 tons capacity, is rotated after entering the hatch, to extend lengthwise of the boat, enabling it to reach the ore tributary to each hatch. It makes the complete cycle or round trip in 50 seconds. A typical installation of Hulett unloaders is that of the Pennsylvania Railroad Co.,

¹ The Author is indebted for the foregoing facts and figures, as well as the illustrations, to an article by A. Bergman, of Stockholm, which appeared in *Zeitschrift des Vereins deutscher Ingenieure* of 28th February 1914.

Cleveland, Ohio, which was completed in 1912 for use on the banks of the great American lakes. It is for handling both ore and coal. It consists of four units, one of which is shown in Fig. 668. The entire machine is mounted on four rails, and has altogether thirty-two wheels, which have been grouped into eight bogies. Fig. 669 shows



Fig. 669. Portion of Structure supporting Hulett Unloader.

one side of the lower structure. The travelling gear receives motion from an electro-motor of 150 H.P. (at 450 revolutions). The carriage of the unloader proper, which travels on this structure, has twelve wheels in front and four at the rear end, and there are



Fig. 670. Hulett Unloader Depositing into Portable Bunker.

also at the back two further wheels which press against a rail above to prevent tilting of the apparatus. The carriage of the unloader supports a balance beam, which carries the unloader itself on its vertical iron arm, whilst the winding gear is situated at the rear end of the beam.

The winding drum of the lifting gear is manipulated by a 300 H.P. electro-motor and electro-magnetic brakes. Four $1\frac{1}{2}$ -in. cables are connected to the drum, and lead

down to the lower part of the structure, where they pass over sheaves and up again to the end of the balance beam. The travelling gear of the carriage of the unloader is connected to a 100 H.P. electro-motor (at 250 revolutions).

The grab is so supported on its column that it can revolve around its vertical axis $\frac{7}{8}$ of a revolution in either direction, so that altogether a movement of $1\frac{3}{4}$ revolutions can be performed; this motion is given by a 35 H.P. electro-motor. The opening and closing of the grab are controlled by chains, which wind and unwind on three drums on one common spindle. The axis of the grab does not coincide with that of its column, but is eccentric by 2 ft. The spindle of the drum for manipulating the grab is connected by two intermediate gear-driven spindles, and by two cables which connect them with the winding gear at the rear end of the balance beam, and are manipulated by a 100 H.P. electro-motor. This gear is also fitted with an electro-magnetic brake and a flexible coupling, which absorb any stresses which might be caused by the closing of the grab. The weight of the grab and its support is balanced to within 4 tons by a balance weight.

Fig. 671. Hulett Unloaders in Hold of Vessel.

The arrangement in this installation is such that the ore can be deposited in a

Fig. 672. Perspective View of Four Hulett Unloaders.

bunker on wheels so that very little time is lost, the grab in order to unload only having to travel back a short distance. This portable bunker is connected with a weighing mechanism, and its contents may be drawn off into railway trucks, etc. Fig. 670 shows the

foremost of the four unloaders depositing its load into this portable bunker, whilst Fig. 671 shows two unloaders in the same hold, one being open and the other closed. This illustration also shows the position of the driver's cabin. Two such travelling bunkers are used so that one can be emptied into railway trucks whilst the other is being filled by the grab. The grab capacity is 17 tons of ore, and as the bunker holds 70 tons, it is practically filled by four grab loads. Three men are required to manipulate one machine. All movements

of the grabs are controlled by one man. The travelling gear of the crane carriage, and the manipulation of the bunker, is under the control of the second man, whilst the third manipulates the under-carriage. The capacity of these Hulett unloaders varies from 500 to 1,000 tons per hour, depending upon the depth of the ore in the hold, and the construction of the ship to be unloaded. As an example may be cited the unloading operations in the dock at Ashtabula, Ohio, in 1913, when eight 15-ton unloaders, working in sets of four, from two separate harbour basins, unloaded 70,000 tons of iron ore from eight steamers in twenty hours—an average of $437\frac{1}{2}$ tons per machine per hour. In this time calculation the berthing of the ships and the making fast in the docks is included. In this case the ore was deposited directly into railway wagons, 1,319 being required, each containing 53 tons, that is, one wagon every fifty-five seconds.

Fig. 673. 10-Ton Grab of Hulett Unloader.

Up to the year 1914 fifty such unloaders had been erected, and with the exception of two were engaged in unloading ore and handled over 50 per cent. of the total tonnage of ore shipped on the great American lakes. The other two, which were erected in 1913 at Fort William,

Fig. 674. Hulett Unloader at Ashtabula.

Ontario, in Canada, for the Canadian Pacific Railway Co., are for the unloading of coal.

This latter plant consists of two automatic unloaders equipped with 8-ton scoops, a man-trolley stocking-bridge carrying a 9-ton grab bucket, and a transfer car system with

trestle and bins. The plant has a capacity for unloading a 10,000-ton boat in fifteen hours. Most of the latest machines are entirely electrically driven; some, however, are driven by steam or hydraulic power.

Unloaders of the Pennsylvania Railroad Co., which grab 17 tons at a time, are shown in Fig. 672. The 10-ton grab of a similar installation of the Corrigan McKimey Co. is illustrated in Fig. 673.

A 15-ton capacity Hulett unloader at the plant of the Pittsburg and Conneaut Dock Co., Ashtabula, Ohio, is shown in Fig. 674.

The Hulett unloader will handle ore at $2\frac{1}{2}$ to $4\frac{1}{2}$ cents per ton, including all fixed charges. The most noteworthy performance on record is the unloading of 783 tons of ore per hour per machine from the mooring to the casting off of the boat.

CHAPTER XXXI

TRANSPORTERS, BRIDGE OR CANTILEVER CRANES

PERHAPS one of the most important improvements that has been effected of late years in the mechanical handling of material is in connection with discharging ships to granaries, warehouses, or stock yards erected on or near the quay side.

The first step in advance which superseded hand labour was taken when cranes were erected and used for the clearance of cargoes. At this stage it became the practice when unloading coal to fill it into skips of cylindrical shape, which were hoisted and then discharged through a hinged door into railway trucks.

This system is still in use to a considerable extent, but it has the disadvantage of calling for an inordinate amount of hand labour, and is therefore economically wasteful. An improvement on this method is the use of grabs which generally require a special kind of crane, and will effect a sensible saving in time. In later years the hoisting crane or transporter has been combined with a bridge or gantry which commands the whole length of the quay side, store, or yard. In or on these gantries mechanical means for conveying the material are erected, and every operation incidental to the reception and further handling of the material is effected mechanically. Such installations have been variously called transporters, bridge or cantilever cranes.

They can be either steam or electrically driven, and it is claimed that the first of the latter type were erected in 1901 by the Brown Hoisting Machinery Co. for the North-Western Fuel Co.¹ They can be divided under two general heads:—

(a) Transporters in which the winding gear is mounted in a movable cabin, and accompanies the load from the ship to the point of delivery.

(b) Transporters in which the winding gear is situated in a cabin fixed in the structure of the crane, and is connected by cables and chains to the running head which carries the load.

TRANSPORTERS WITH MOVABLE WINDING GEARS

These transporters are perhaps not so much used as those with stationary winding gears, probably for the reason that the structure has to be erected on a more substantial scale, and is therefore more expensive. It has, however, several advantages, the principal one being that the handling of the material is better under control of the attendant as he accompanies the load in his cabin, which also contains the winding gear and motor.

Such transporters are numerous, but as they all bear a great resemblance to each other, it will suffice to give only a few examples.

Electrically Driven Grab Transporters at the Coal Yard of the British Admiralty at Devonport.—The British Admiralty have erected four electrically driven grab transporters, forming one installation, part of which is illustrated in Fig. 675. It

¹ Described by Mr G. H. Hutchinson, chief engineer, North-Western Fuel Co., in his paper presented to the American Society of Mechanical Engineers.

will be observed from this that the transporters are of very large size, and that the driver with his cab accompanies the load.

These particular machines are arranged to travel around a sharp corner in the store

Fig. 675. One of Four Electrically Driven Grab Transporters for British Admiralty.

ground, and also to stand at varying angles to the track. Two machines can stand at such angles that the grabs can work from the same hold, but discharge the coal to different portions of the yard. The advantage of such an arrangement is readily understood. Similar conditions can be obtained when loading vessels from the store.

The machines run on double rails at each end, placed close together, and no square tower is provided. The transporters were arranged in this way so that very little space near the quay front should be taken up by them and that quay cranes could pass between the coal heaps and the transporters. Each machine is provided with a 2-ton grab, and can discharge coal from the collier to the centre of the coal yard at the rate of 100 tons per hour. The length over all of the transporters is nearly 400 ft., and the height of the lower chord of the bridge above rail level is 34 ft. The depth of the bridge is 19 ft. This method of unloading coal cost $\frac{3}{4}$ d. per ton in pre-war days, which included driver, and current consumed.

The special advantage of this system in combination with grabs is, that the coal can be stored to a greater height than when handled by buckets. Coal is never stacked, in British dockyards, more than 18 to 20 ft. high by the latter method, whereas it can be safely stored to 34 ft. by transporters and grabs. This means an increase in the capacity of storage ground of nearly 100 per cent., which often proves to be of very great value indeed where space is restricted. Careful observations show that heating does not take place when this depth of coal has been stacked by such grabs.

It is claimed for these installations that they are more economical in working than the rope-haul system. Other advantages claimed are: that the driver has a perfect view of his work under all conditions; the track is not confined to a straight line; the parts to be kept lubricated are all collected in one cabin; and all rope sheaves are entirely omitted. The power required to drive is less in this system, as very little is lost between the gear and the grab compared with that lost when ropes have to be led around a large number of pulleys. The installation was erected by Fraser & Chalmers, Ltd., of London and Erith.

Coal-Handling Plant at Duluth.¹—A plant which is said to be the largest in the world for handling bituminous coal was completed in 1911 at Duluth, Minn., for the Pittsburg Coal Dock Co., a subsidiary of the Pittsburg Coal Co. The plant is designed for unloading coal from lake boats to the storage yard, and for loading on to cars. An interesting feature is a mechanical screening apparatus. The plant has a storage capacity of 1,000,000 tons, and an unloading capacity of 900 tons an hour, including the delay in cleaning up the holds of vessels unloaded. While working in free coal it is estimated that the plant will discharge 1,500 tons an hour from a boat to the storage yard. The installation was designed and erected by the Brown Hoisting Machinery Co., Cleveland, Ohio.

The coal-handling equipment includes three two-span bridges, shown in Figs. 676 and 677, extending from the unloading dock, and two single-span bridges. Each span is of 242 ft. The yard is covered by the bridges, which are operated back and forth on a runway 1,250 ft. long. Each two-span bridge and one of the single-span bridges is equipped with a man trolley, which carries a two-rope Brown grab, with a capacity of 230 cub. ft. or $5\frac{1}{2}$ tons, and an operator's cab. The single-span bridges are arranged to register with any of the two-span bridges in order to make a three-span bridge or a continuous runway for a trolley over any one of the two-span bridges and one of the single spans, a total distance of 726 ft. The operating mechanism is arranged so that when a single-span bridge is connected with a two-span bridge the three spans are negotiated as one unit. The single spans may also be operated as independent bridges. The single span not provided with a trolley is operated by using one of the trolleys from a two-span bridge. The two-span bridges have a cantilever extension of 78 ft. out over the

¹ From *The Iron Age* of 7th December 1911.

dock and there is a 35-ft. cantilever extension from the rear end of each of the single-span bridges.

Each man trolley is designed to carry a load of about 10 tons, to hoist the full load of the bucket at the rate of 225 ft. per minute, and to travel along its runway at 1,200 ft. per minute. Each bridge, when carrying a loaded bucket, can propel itself along its own runway at a speed of 60 ft. per minute.

The front or water end of each two-span bridge, Fig. 677, is carried on a portal pier equipped with bins for loading coal into hopper or gondola cars. The centre and rear end of the two-span bridges and the forward end of the single-span bridges are carried on shear legs, each running on a single line of rail. The rails are supported on trestles constructed of steel girders carried on steel A frames. There is one single rail trestle or runway, and one double rail trestle. The former is for the shear leg at the centre of the two-span bridges, while the latter is for the rear shear leg of the two-span bridges, and the shear legs of the single spans. The distance from the foundations to the top of the rail on the trestles is 35 ft. 6 in. The rear ends of the single-span bridges are carried on inverted piers.

The piers for the two-span bridges are each supported on four equalising bogies, each being mounted on four 24-in. double-flanged, cast-iron, chilled-tread wheels. The wheels on each pier are connected by a train of gearing and shafting to the moving gear mechanism located on the bridge span, near the bridge support. Each inverted pier at the rear end of the single spans is carried on two sets of equalising bogies, each supported on eight similar wheels. In addition the rear pier which carries the screening apparatus is provided with one equalising bogie supported on six 24-in. wheels, each travelling on two lines of rails spaced 2 ft., centre to centre. The six-wheel bogie acts as an idler only. All of the wheels in each of the eight-wheel bogies are driven, being connected by a train of gearing and shafting to the moving gear mechanism located at the top of the pier. Under the other rear pier one half of the wheels are similarly connected to the moving gear mechanism. Each shear support in the bridges is mounted on two single-rail equalising bogies, each being supported by four wheels.

Fig. 676. Coal-Handling Plant at Duluth.



Fig. 677. Front Ends of two of the Two-Span Bridges at Daluth, that in the Foreground being in Extended Position.

The shears support the bridge span on sliding bearings under the top chords. The cantilever extensions from the dock end of the two-span bridges are supported from the tops of masts over the pier (see Fig. 677). Attached to the cantilevers are hinged aprons that can be raised and lowered. The moving gear for each bridge crane is operated by a motor in a house over the pier support. This motor is controlled from the operator's cab on the man trolley, when the trolley is brought to a point immediately under the moving gear house. The man trolleys are so designed that the operator can turn the bucket through an angle of 90°.

The mode of operation of the screening apparatus at the rear is generally as follows: The coal is first placed by the grab in a 30-ton receiving bin. It is then passed over a shaker screen to a pivoted conveyor for delivering it into cars. The coal going through the shaker screen passes into a small bin beneath, delivering to an elevator, by which it is either delivered to revolving screens for preparing small sizes, or directly into the screening bin for delivering it to a belt conveyor discharging on a screenings stock pile.

By this arrangement, when lump coal is being loaded, a car load each of stove, nut, and screenings may be taken at the same time. In case lump coal is being loaded and there are no orders for the smaller sizes, the screenings can be delivered from the elevator direct to the screening bin, which in turn will deliver them to the belt conveyor for the stock pile. When taking general screenings from the stock pile for sizing and loading, they are dumped by the grab into the receiving bin and handled as described. The bins are of parabolic form. The 30-ton bin is equipped with a large reciprocating gate operated by power. The screening apparatus for handling the coal passing through the shaker screen has a capacity of 200 tons an hour. The other rear pier is equipped with a 30-ton bin, gate, and shoot for unloading coal into gondola cars, a screening bin and elevator for screenings, and shoots for unloading screened coal into box cars in connection with box-car unloaders. Beneath the screening shoot is a 50-ton bin for catching the screenings. In connection with this equipment is a bucket conveyor for raising the screenings to a point from where they are discharged by gravity to a pile on the water side of the pier, or carried by a belt conveyor and discharged in cars on the second track on the other side of the pier.

The electrical equipment is arranged to operate on 440-volt, 3-phase, 25-cycle, alternating current. The motor equipment includes the following, in addition to the motors in connection with the screening apparatus, all furnished by the General Electric Co.: three 112 H.P. motors for moving the three two-span bridges and a 112 H.P. motor for operating the single-span bridge that has the extensive screening equipment; one 50 H.P. motor for moving the other single-span bridge; one 225 H.P. motor in each of the four trolleys for hoisting; two 112 H.P. motors in each trolley for the trolley travel; one 5 H.P. turntable motor in each trolley for rotating the grabs; one 2 H.P. clutch motor in each trolley, and one 15 H.P. continuous running motor for operating the screening elevator and conveyor in the pier of the single-span bridge not containing the screening equipment; the travel motor on each bridge is operated by a general electric drum-type controller; the hoist motor on each trolley by a master-operated magnetic controller; the trolley travel motors are each operated by a master-type controller.

During tests of the plant the steamer "J. S. Ashley," with 8,983 tons of lump coal, was unloaded in ten hours and fifteen minutes, and the cargo of the "J. E. Upson," 8,747 tons of the same grade, was taken out in ten hours and fifty-five minutes actual working time. While working in free coal, each bucket averaged nearly 6 tons to the lift.

In 1913 a similar installation with longer span bridges was erected on the Pittsburg Coal Co.'s Dock No. 5 in Superior, U.S.A.

Electric Travelling Trolley of the Brown Hoisting Machinery Co.—

A most important part in high-level cranes is the trolley with its motor. It can, of course, travel on any gantry or bridge of suitable construction. Such a trolley is represented in Fig. 678.

The illustration explains itself. This trolley is used to draw ore and limestone for blast-furnace purposes from ore bins, and convey it to the furnace hoist, where the bottom door of the receptacle is opened and the ore discharged into the skip.

Electric Travelling Trolley of the Temperley Transporter Co.—Such a travelling trolley fitted with a Hone grab is illustrated in Fig. 679. It is shown with its electro-motor, also the cable from which the current is taken. The operator's seat, and the levers, by means of which the trolley as well as the grab are manipulated, are also shown.

Fig. 678. Electric Travelling Trolley as used for Feeding Furnaces.

The capacity of the grab is 3 tons; it rises 50 ft. per minute, and the trolley travels at a speed of from 400 to 500 ft. per minute.

For other examples see Chapter XLI. on "Storing Coal and other Minerals in Stock Heaps and Silos."

TRANSPORTERS WITH STATIONARY WINDING GEARS

These undoubtedly owe their origin to American enterprise, and are largely used in the United States in a variety of forms, similar in appearance and general operation to that in which the winch accompanies the load, but the structure need not be so substantial, as smaller loads are generally dealt with, and in addition to the load the weight of the traveller or running head only need be taken into account as against the weight of the movable cabin with the winch and motor. But as this type is sometimes built from 60 to 80 yds. in length, the construction must be sufficiently rigid to resist, in addition to its own weight, the influence of high winds. It has also this advantage,

that the velocity with which the load can be moved is greater than when a travelling cabin is used and a heavier load has to be handled; the speed being from 12 to 14 ft. per second, as against 5 to 6 ft. per second in the other type.

American transporters generally run at higher speeds than those usual in Europe; too great a speed is, however, not advisable, on account of the strain due to the stopping and starting of the running loads. The principal difficulty with bridge cranes with fixed winches is the complicated leading of the rope or ropes, and the consequent great wear and tear on the ropes caused either by their being bent in two directions, or by their being led over small sheaves. The use of chains would obviate this difficulty; but these are unsuitable, not only on account of their weight, but also because they lack the elasticity of wire ropes, and are therefore more likely to break under the strain caused by the sudden stopping and starting, and also by the shocks occasioned by the use of grabs at the loading end of the apparatus. It is probably on this account that some firms prefer to fit their transporters with ordinary skips instead of mechanical grabs. With the latter the wear and tear on the ropes is certainly greater. Instances have been known where wire ropes have had to be replaced after working only a few weeks. If

Fig. 679. Electric Travelling Trolley fitted with a Hone Grab.

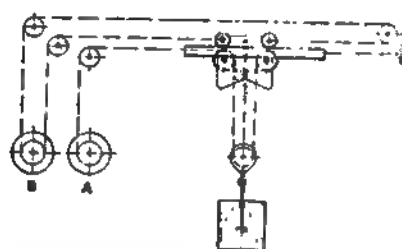


Fig. 680.

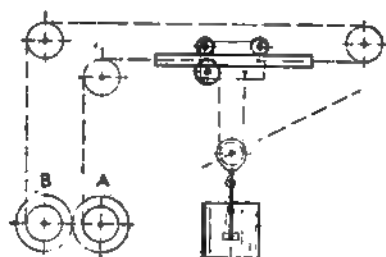


Fig. 681.

grabs are used the one-rope type is preferable, because a two-rope grab will complicate the handling of the plant.

Another difficulty in the use of transporters with stationary winches arises from the fact that the man manipulating the winch cannot control the operations so well as if accompanying the load. It is, therefore, sometimes necessary to employ a signaller in a prominent position who can communicate with the men in the hold and the

operator in the winch cabin. These minor disadvantages have, however, not materially checked the progress of this type of crane, as its quicker unloading speed, easier manipulation, and smaller first cost have opened up a large field for it.

The illustrations, Figs. 680 to 690, show, by diagrams, the most usual forms of manipulating the traveller, with its load, from the winch or winches. Transporters of this type are by no means new, but have been used for a number of years on a small scale on the principle shown in Fig. 680, where the rope which lifts the load is fixed at one end of the structure, and at the other to the drum A, and supports the skip after passing over the fall-block. If the position of the running head is changed by the drum B, the load remains at the same distance from the ground. A represents the drum for raising and lowering the load, whilst B is the winch for moving it horizontally. The constant bending of the steel rope over the two pulleys on the traveller and over the fall-block offers considerable resistance to the movement of the load; yet over short distances such transporters do satisfactory work. For long lengths and for a quick rate of travel this construction is unsuitable. It can, however, be used to advantage when the load is so held as to relieve the rope during the lateral movement of the running head, as shown in dotted lines, when the fall-block is held in its topmost position by a catch suspended from the running head. In such a position, and with the load supported by the head itself, the rope will bend freely and without much wear and tear during the horizontal movement of the load. The position of the load close to the running head is also an advantage, as it checks the swinging, pendulum fashion, and admits, therefore, of a quicker starting and stopping, but it must be raised to its fullest extent and locked before the horizontal movement can take place. This also entails a small loss of time for the locking and unlocking of the load in its raised position. When ore or other material that does not deteriorate by being dropped is being conveyed, it will be unnecessary to disengage the fall-block, and lower the load down to the pile before tipping the bucket.

Such difficulties as are met with in the device shown in Fig. 680 are obviated in the scheme illustrated in Fig. 681. In this both conveying and elevating ropes are under the same tension. The two drums A and B are loose on their spindles, which are, however, coupled together by spur wheels, the drums being connected to the spindles by friction clutches, either separately or jointly. The drum A is for elevating only, but both drums A and B must be in motion when the traveller is moved in either direction. This construction enables the operator by simply pulling the hauling ropes to raise or lower the loads in an oblique direction; as is indicated by the dotted line in Fig. 681. The angle is 2:1 to the horizontal. The side movement of the load is, therefore, twice as great as the up-and-down movement, but the proportion can be altered by using different fall-blocks, or to meet cases where the motor speed varies according to the load. Where short chains are used in conjunction with grabs, this oblique movement of the load is most convenient. The principal advantage is that the horizontal and vertical movements are independent of each other, and that the traveller may be moved horizontally with the load in any position. For transporters with high speeds it might be an advantage to convey the skip in as high a position as possible, to avoid the pendulum movement. With this construction both winches A and B must be of the same power, as both ropes are under the same tension.

A similar design is shown in Fig. 682. Both winches A and B can be turned either in the same or in opposite directions, this being accomplished by the use of a pair of wheels, of friction clutches, and of a third wheel C, which can be coupled between the two larger spur wheels. If both drums revolve in the same direction, they both wind up

the rope, and thus elevate the load; whereas, in the other case, one drum winds up as much rope as the other pays out, and the load is therefore conveyed in a horizontal direction.

In a scheme such as is illustrated in Fig. 683, the load is supported on an endless rope which is wound round the conveying drum B, and by means of this drum can be drawn either backward or forward. The drum A is for lifting and lowering the load by shortening or lengthening the endless rope which supports it, this being accomplished by a pair of jockey pulleys, as shown in the illustration.

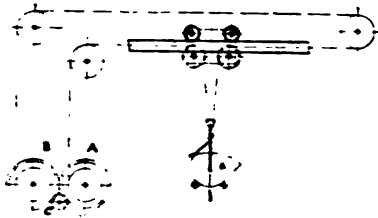


Fig. 682.

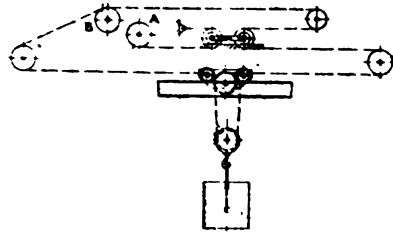


Fig. 683.

The demand for transporters with less complicated winding gear led to the introduction of those worked by one rope only, and their action is illustrated in Fig. 684. One end of the rope is attached to the winding drum of the winch and the other to the traveller. Supposing the winch to be standing, the load would descend by its own gravity and move the running head or traveller in an upward direction; but in order to prevent this, the traveller is secured to the girder upon which it runs by a catch and notches

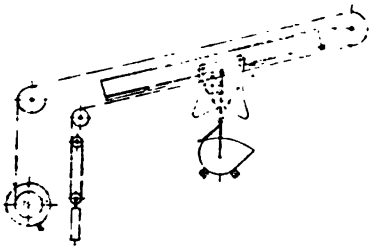


Fig. 684.

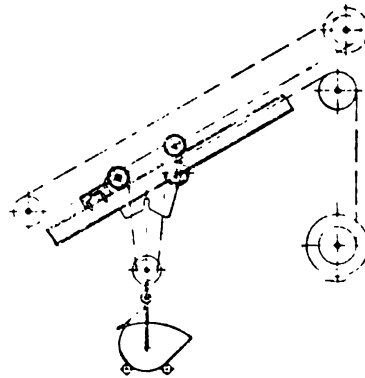


Fig. 685.

cut in the girder. As soon as the load has been raised to its topmost position, and the fall-block has entered the traveller as shown, it is retained there by a hook, which automatically releases the catches that locked the running head to the girder. On a further movement of the winding drum, the load proceeds in an upward direction, and when empty, the running head returns automatically down its own support. The crane is manipulated as follows: The traveller is pulled by the winch past one of the notches near which the unloading is to take place. The rope is then somewhat slackened to allow of a slight return of the traveller on its support, whereupon the catch will engage with one of the notches, and lock it in position. At the same time this releases the load,

and by slackening the rope the load will be lowered. In order to accelerate the return of the traveller, the incline of the girder is placed at about 1 : 4. This is necessary, as the weight of the rope has to be drawn along with the head. If such an incline be prohibitive on account of local conditions, or if the transporter be of sufficient length to cause the weight of the rope to hold the traveller back, or to prevent it moving at a sufficient speed, a balance weight is used to accelerate the downward movement as shown.

Another and frequently used method, which is practicable for working with one rope, is illustrated in Fig. 685. The skip is here suspended from the fall-block in the usual manner, and the supporting girder for the traveller is fixed at an angle of about 30° , which angle is sufficient to prevent the running head with its load from moving upward when the winch is at a standstill. In fact, if the angle be made steeper, the load is inclined to run downwards, so that it is necessary to provide a stop block in order to prevent it from running too far. In the position shown, the load can be raised or lowered while the traveller remains stationary, but when raising the load beyond the topmost limit, so that it touches the traveller, the latter with its load will ascend the girder, and the load can then be discharged. The empty skip can only be lowered when the running head comes against an adjustable stop, as shown. The fact that this system requires such a very steep rail girder will account for its use being confined to comparatively short reaches,

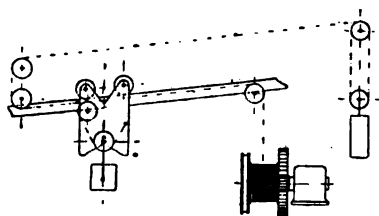


Fig. 686.

and to its mostly being used for unloading ships in connection with other methods of conveying, the transporter in this case only being used to transfer the material from the ship's hold to a conveyor which takes it to its destination; whereas transporters with horizontal or slightly inclined rail girders are more generally used to convey the material from the ship to its final destination without the intervention of an auxiliary conveyor.

The transporter of the Brown Hoisting Machinery Co. is usually made so narrow that, as we shall presently see, three or four can be placed close together to unload from the same ship, or at least one can be set to work over each hatchway.

The manner in which the rope is connected from the winding drum to the traveller or running head is shown in Fig. 686, whilst Figs. 687 and 688 show the details of the traveller itself.

As long as the load is being elevated, the traveller is mechanically fixed, and is therefore prevented from following the direction of the hoisting rope. As soon as the load is lifted sufficiently high for the fall-block to touch the traveller, the latter is uncoupled, and the load automatically held in that position, so that any further winding of the rope will move it in a horizontal direction. When the load has been discharged, the traveller returns, its speed being controlled by a brake, until it has reached the point where it fixes itself, after which the further slackening of the rope will permit the descent of the skip. The incline of the girder is in this case 1 : 8; but this not being sufficient to allow of the traveller going back on its own account, a travelling rope with a balance weight had to be used for the return of the empty skip as shown. The traveller is represented in Fig. 687 at the moment when it reaches the lowest point determined by the fixture *a* which enters into the space provided for it in lever *b*₁, and couples itself as shown in dotted lines as soon as the traveller reaches the end of its journey. The lever *b*₂ is moved simultaneously, thus giving rod *c* a downward motion. This action also moves lever *d*, which swivels round point *e* to the right at

the top, and to the left at its lower end. This action releases the pulley and the fall-block with the load. The skip is now descending, and whilst doing so the head or traveller is held in position by lever b_1 . After the skip has been filled and raised, the projecting spindles of the fall-block touch the forked end of rod c , which is thereby raised, so that b , b_1 , and d are all replaced in their original position. Thereupon a is released by b , and lever d again holds the load, which, with the traveller, can proceed to the right. The skip is made to discharge its load automatically. It has a natural tendency to tip forward, but is prevented from tilting by the levers, which rest in grooves on the sides of the skip.

The traveller is fitted with levers $g g$, which are held in position by springs in the tube h . One end of the lever is fitted with rollers $i i$. These rollers touch trippers $k k$ which are fixed in the discharging position. Thus the levers $g g$ will be lowered by the incline on trippers $k k$ until they come in contact with levers $f f$, and release the skip, allowing it to discharge itself. This method of unloading is, of course, only used when



Fig. 687.

Fig. 688.

minerals are being handled, as a fall from a height would in the case of coal be detrimental.

Fig. 688 shows a cross section through the trestle bridge of the transporter. The crane can be moved at the rate of 3 ft. per second; whilst the movement of the traveller is 13 and 20 ft. per second when moving in an upward and downward direction respectively. The capacity is from 300 to 500 tons per day of ten hours, eight or more trimmers being employed to fill the skips.

In the latest transporters of this type the rope is guided as shown in Fig. 689, from which it will be seen that the lifting and conveying ropes are running on separate drums. The two winding drums are loose on the spindle, and are connected by two bevel wheels and four pinions. The four pinions are mounted in a ring which can be fixed or allowed to run loose. All drums are loose on the spindle, and can be coupled to it by friction clutches. This transporter has the advantage of dispensing with the use of more or less complicated fixed stops. It can be stopped and unloaded at any point, and the skip need not be lifted to its topmost position before the traveller is put in motion, for if both conveying and lifting drums are started, the traveller with the skip will rise in an oblique direction, which movement can be utilised to fill the skip from a heap of material lying at its natural angle of repose.

The winding gear with its rope connection, shown in Fig. 689, can also be modified in so far that the lifting drum can be dispensed with (see Fig. 690). Such a device is used by the C. W. Hunt Co., and also by the Brown Hoisting Machinery Co. The ropes are in this case both run over the sheaves in the traveller and secured to the suspender on which the skip hangs. The winding gear works as follows:—

The drum 1 is cast together with its driving wheel. It is keyed to the spindle, and can move in both directions. Drum 2 can be coupled to the spindle by the friction clutch R. Both drums receive and pay out rope on the same side, and are coupled together by gearing as shown in Fig. 689. The ring B in which the four bevel pinions are fixed can be held by a band brake. If the load is to be elevated, both ropes are thrown in, the effect being that both drums revolve in the same direction, and as the four pinions are not fixed, they revolve freely, and are therefore out of action. The load can, by means of the band brake, either be held in suspension or lowered. If the traveller runs either forward or backward, the drums must revolve in opposite directions.

The Temperley Transporter.—In conveying coal, grain, and other heavy goods, the Temperley transporter, now manufactured by Sir William Arrol & Co., Ltd., of Glasgow, has undoubtedly rendered excellent service. It is used for the delivery of coal from

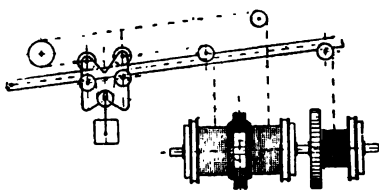


Fig. 689.

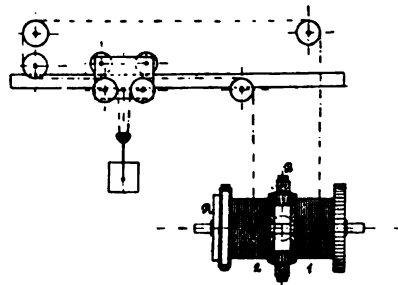


Fig. 690.

lighters or barges, as well as from vessels lying at wharves, into boiler-houses, while it has also been found most useful for the loading and unloading of grain vessels.

This appliance is so largely used that it is worthy of a full description. Joseph Temperley, the inventor, had for many years been engaged in the shipping industry in London, and had observed the inadequacy of old-fashioned methods of discharging vessels in the Port of London. His invention dates from about the year 1892, when turret ships and whalebacks first made their appearance. The original Temperley transporter consisted essentially of a long I-shaped section beam with a traveller running on the lower flange. The beam was triced up to the movable framework or shear legs, whilst the traveller was worked by two ropes engaging on the two drums of a double-barrelled winch. The apparatus was so arranged as to command the hold of a vessel and a point from 20 to 30 ft. overboard. This was the earliest type as designed for turret ships, but the inventor was not altogether satisfied with his work, as the apparatus appeared to him rather too complicated for general use, especially on board ordinary cargo steamers which have their own winches, and which carry derricks from which the beam of the transporter can be suspended. He accordingly simplified the gear, so that his appliance could be used with an ordinary ship's winch on which a single rope is paid out or hauled in.

In the later transporter the running head or traveller is fitted with an ingenious automatic device, by means of which it may be arrested and held stationary while the load is being either lifted or lowered. This device also keeps the load in suspension while the

traveller is moving. The British Admiralty and many foreign Governments have adopted and successfully applied the transporter to the rather difficult task of coaling warships.

Temperley transporters are used under a great variety of conditions, both in the portable and fixed type on staging, or on gantries, at inland points, as much as, and perhaps more than, for harbour work. The original length of track of 40 to 50 ft. or so has now been extended to ten times as much, or even more, whilst the speed of lifting and travelling, which, in the early days, was about 150 ft. per minute, is now raised to a speed of 1,400 ft. per minute. It was, of course, inevitable that this great increase of speed should necessitate the use of better winding gear, and the simple winch which was originally used is quite inadequate for these modern high-speed installations. This transporter consists of three principal parts, namely, of a steel beam of Γ -section, which may be hung from the ship's mast or derrick, in which case it would vary in length from 30 to 65 ft., or as an alternative it may be supported on shore by an ironwork trestle frame, in which case the length of the track may be considerably extended; secondly, of an automatic traveller; and thirdly, of a winch which operates the traveller by a wire cable.

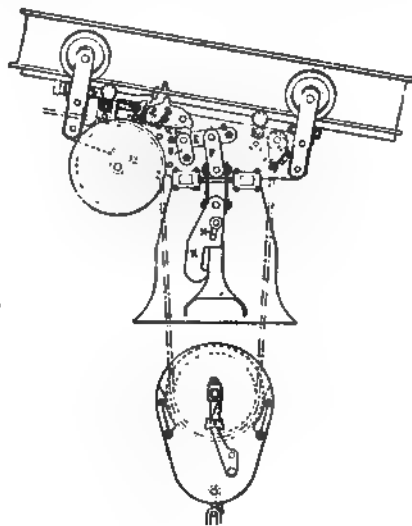
Assuming this transporter were being used on board ship, it would be attached by wire slings to the end of an ordinary derrick, and would then be held up and secured by guy ropes in an inclined position across the vessel to command both the hatchways and the quay, or any lighters or barges which might be alongside. The pulley end of the Γ -shaped beam should be higher than the other end, towards which the movement of the traveller is effected by gravity. The angle at which the beam is inclined may be varied to suit the precise nature of the work. The beam may project over either side of the vessel. It remains in a fixed position, and should be quite rigid when at work, except that it should be free to swing laterally on its swivels. A steel wire rope is passed over the sheave of the traveller and runs over the fixed pulley at the end of the beam, and over two leading blocks, one being placed at the head and the other at the heel of the derrick. This wire rope is attached to the drum of an ordinary steam winch which is placed on the deck of the vessel.

The load can be discharged at any number of fixed points on the length of the beam. Such points or stops are usually placed about 5 ft. apart, all these operations being under the control of the attendant.

The traveller or running head is made in two distinct forms; one being double purchase with fall-block, and the other single purchase without fall-block. The former is shown in Figs. 691 and 692. In each case the traveller is held in position on the beam by the locking block *B*, whilst the load is being lifted or lowered, and, on the other hand, the load is sustained by the hooks *K* whilst the traveller is being moved along the beam. The locking block *B* and the sustaining hooks *K* are connected together by a system of levers and links in such a manner that the movement of the block *B*, in the act of locking the traveller to the beam, withdraws the hooks *K* out of gear with the fall-block—which is then free to descend—and conversely, the movement of the hooks into gear with the fall-block effects the release of the traveller from the beam. An important feature is that the relative movements are so arranged that the movement of the block *K* into gear with the beam is almost complete before the hooks begin to withdraw from the fall-block, and, on the other hand, the movement of the hooks into gear with the fall-block is almost complete before the block begins to come out of gear with the beam. Also, although *B* actuates *K* to release the load, and *K* actuates *B* to effect the release of the traveller, the final small movement to complete the locking of the traveller and the sustaining of the load is in each case forcibly completed the other way about.

That is, the weight of the escaping load completes the revolution of the block *B*, and the forced revolution of the block *B* in coming out of gear with the beam forces the hooks into complete gear with the fall-block. It will be noticed that in both positions, Figs. 691 and 692, all the parts are securely locked by two pairs—lever and link—just over the dead centres.

In Fig. 691 the fall-block is "home" in the traveller, and the latter is unlocked from the beam on which it runs, and can be drawn along the transporter beam, the load during its travel being supported from the hook marked *K* in the figure. Should, however, the hauling rope be paid out instead of being hauled in, pawl *A* catches on the notch, causing block *B* to rotate on its pivot, and its projecting tooth to engage in the large notch shown. The weight of the traveller, tending to make it slide down the beam, causes block *B* to begin to rotate into the position shown in Fig. 692, the rotation being forcibly completed by the weight of the load dragging down the hooks and forcing two pairs of



Figs. 691 and 692. Showing Sliding Block and Traveller of Temperley Transporter.

links *E G* and *C D* a little beyond the straight line—or dead centre—thus forming a double deadlock to the system. One end of this block is connected to a system of links lettered *C, D, E, F, G*. In Fig. 691 the links *D* and *E* are nearly in a straight line, and thus the weight of the fall-block, which is in position, as shown by the link *F, G*, exerts no pressure on block *B*. What little pressure there is tends to keep *B* against its stop in the position there shown. Referring to Fig. 692, the tooth on *B* engages with a notch, and by means of link *C* pulls the two links *D* and *E* into the position shown. The hook *K* and the link *F* then descend, being dragged down by the weight of the fall-block. The hook is provided with a cam slot shown at *H*, in which engages a fixed pin. This cam slot is of such a shape that as the hook *K* descends it is swung to the left, as shown in Fig. 692, thus releasing the fall-block, which, on paying out the lifting rope, descends freely, completing the rotation of *B*, explained above. On raising the block again, striking pieces on it will come in contact with hook *K*, and raising the latter, will force up link *F*. The latter, by means of link *E*, will then pull over links *C* and *D* from position shown in Fig. 692 into that shown in Fig. 691, thus unlocking the traveller, and at the same time hook *K*

comes again into position to suspend the load. That is to say, the conditions of Fig. 691 are restored, except that the small pawl A now slopes up to the left instead of to the right, as there shown. It therefore follows that on slackening the rope, this pawl no longer catches on the beam, and the traveller is free to run down the latter on paying out the hauling rope. Generally the traveller is, in these circumstances, allowed to run to the very end of the beam, where a projecting block of metal catches the tooth on the block B, which thus locks itself without any assistance from the small pawl, but the traveller can also be brought to rest at any intermediate point.

When the traveller is locked to the beam, as shown in Fig. 692, lifting or lowering is accomplished by hauling in or paying out the rope in the ordinary way. If it be desired to release the traveller, the operator has only to haul in the rope until the fall-block has entered the bell, and in so doing has brought the mechanism of the traveller into the position shown in Fig. 691, when the traveller is free to move either up or down the beam. If it be desired to cause the traveller to move up the beam, the operator has only to continue to haul in the rope until the front part of the traveller has passed the point at which it is desired to lower, when, by a reversal of the winch, the traveller will engage with the first stop it encounters, and the load will be lowered. If the traveller is to descend the beam, all the operator has to do, after having released the traveller, is to pay out the rope and it will descend along the beam—passing all the intermediate stops because the toggle has not been cocked and is therefore inoperative; the arresting of the traveller at the intermediate stop when moving down the beam is a very simple matter. It is only necessary to allow the carriage to pass the stop, when, by drawing it back in an upward direction, the toggle will become cocked, after which, as the rope is again paid out, the traveller will engage with a stop, and the load be lowered at that point. As the traveller moves up or down the track, the cam tooth can pass a stop with a clearance, but as the cam reaches the bottom stop it will, without the cocking of the toggle, automatically engage with it, and as the rope is paid out, the load will automatically be lowered.

The mechanism for dumping and travelling, described below, is in reality the gear which deserves to be called automatic. Position A, Fig. 693, shows the dumping mechanism when the loaded skip is being lifted, the dumping mechanism of the fall-block having been thrown completely out of gear by the setting lever being placed in the position in which it is shown.

On the fall-block entering the traveller, the dumping mechanism is brought into the relations shown in position B, by the point of the sustaining hooks 31 throwing the setting lever 37 into the position shown in this diagram. In this position the load is carried either up or down.

On the traveller engaging with a stop on the beam at the point at which it is desired that the load should be lowered, the fall-block is released from the traveller, and the position of the dumping mechanism is altered to that shown in position C, Fig. 694. It will be observed that the dumping toggle 47 has been turned over, and is pointing in the opposite direction.

With the mechanism in this position the skip is lowered to the point at which it is desired to discharge its contents.

On commencing to lift, the dumping toggle 47 engages with the notch 34 on the periphery of the fall-block sheave, and by the continued movement of the sheave the latch of the skip is pulled out of gear by the wiper 58 and its chain acting through the lever 64 and the chain 65 attached to the latch of the skip.

A special feature of the dumping fall-block is the setting lever 37, by means of which

the dumping mechanism is thrown entirely out of gear, so that by no possibility can the skip be automatically upset while being lifted from the weighing machine. If the men omit to throw the dumping mechanism out of action by the movement of the setting lever,

Figs. 693 and 694. Showing Various Positions of Traveller and Skip of Temperley Transporter.

the bucket immediately upsets on the commencement of lifting. Thus the operators, although they cannot be hurt by the upsetting of the bucket, are forcibly reminded of the results of their negligence.

A later form of this transporter has been fitted with two-rope grabs for handling hard lumpy coal, and similar material, with the advantage that the lifting and lowering can be carried on whilst the traveller is being transported along the beam without either operation interfering with the other.

In the single purchase form of traveller there is, of course, no fall-block, the load being lifted direct on the lifting rope, which is provided with a ball for the purpose of actuating the mechanism in the same way as is done by the fall-block in the double purchase form. The arrangement of the system of interlocking links, etc., remains the



Fig. 695. Temperley Travelling and Slewing Transporter.

same, but the method of suspending the sustaining hooks is modified to suit the conditions. In this traveller the bell is articulated transversely and longitudinally, permitting of a universal movement which allows the load to swing or be lifted from any point considerably removed from the point vertically underneath without chafing the rope.

Fig. 695 shows a Temperley Tower Transporter, which, in addition to the ordinary motions of lifting and lowering, transporting and travelling, is fitted with slewing gear. The tower is mounted on a carriage on which is a track for the slewing wheels to run on, and this enables the whole superstructure to revolve. The advantage of this, when picking up goods from several railway lines and placing them in any part of a barge or small vessel, is obvious.

The principal dimensions of this transporter are:—

Total transporting distance	-	-	-	-	139 ft.
Maximum overreach over water to centre of track	-	-	-	-	96 „
Maximum overreach over land to centre of track	-	-	-	-	43 „
Gauge of track	-	-	-	-	26 „
Working load	-	-	-	-	2½ tons.

Temperley Transporter at the Vizcaya Works, Bilbao.—A typical installation of the Temperley transporter may be seen at the Vizcaya Works, Bilbao, in Spain, where it is used for discharging coal to be converted into coke for the blast-furnaces. This transporter is of the travelling tower type. It works at a speed of 700 to 800 ft. per minute along the beam. On reaching the point at which it is desired to lower the load, the driver stops his engine and throws the hoisting drum out of gear. Thereupon the traveller commences to run down the beam and automatically engages with the first stop it meets as already described. By continuing to pay out rope, the skip and its contents are lowered by the brake, until it is a foot or two from the ground or at the top of the stock heap. Then, on commencing to lift, the bucket will automatically discharge its contents. As the driver reverses the engine, the traveller with the empty skip runs down the beam under the control of the brake at a speed of from 800 to 1,000 ft. per minute. On reaching the bottom stop over the vessel, the traveller automatically engages and releases the fall-block, the driver continuing to pay out rope until the skip has reached the bottom of the vessel. The cycle of operations with a 1½-ton load occupies one minute.

The Temperley Transporter at the West Middlesex Waterworks, Hammersmith, is for unloading coal from barges to stock heap. It is illustrated in Fig. 696, and consists of a fixed transporter for loads of 30 cwt., lifting at the rate of 150 ft. per minute, and transporting along the beam at a speed of 800 ft. per minute, the total length of the beam being 328 ft. The travelling transporter is for the same load and speed, and the total length of the beam is 100 ft. The fixed transporter takes its loads from the barges and conveys them over a public footpath and two boilerhouses, and delivers either to these boiler-houses or to the store yard beyond. The travelling transporter can command the whole length of the yard, and is also used for bringing the coal to the fixed transporter which conveys it to the boiler-houses.

The Temperley Transporter at West Ham Electric Station is shown in Fig. 697. It conveys the coal from the canal to the bunkers over the boilers. The length of this transporter, which has a capacity of 2 tons, is 298 ft. The height of the lift is 45 ft., and the length of beam 315 ft.

Temperley Transporter at Woolwich Arsenal.—An illustration of this interesting installation is given in Figs. 698 and 699, the latter being a photographic view. One of the transporters is shown with its jib end extended in working position, whilst the other is shown with its jib end moved out of the way.

These transporters command a range of travel of 170 ft. and are for loads of 1½ tons. They are used for shipping military stores at the Royal Arsenal.

Temperley Patent Grab Transporters.—The more general advantages of a Temperley transporter are accentuated when the hoisting and transporting of material in bulk is effected by means of high speed grabs. These transporters are accordingly fitted with hoisting and transporting machinery, by means of which the operations of hoisting and lowering and that of transporting may be carried on separately or

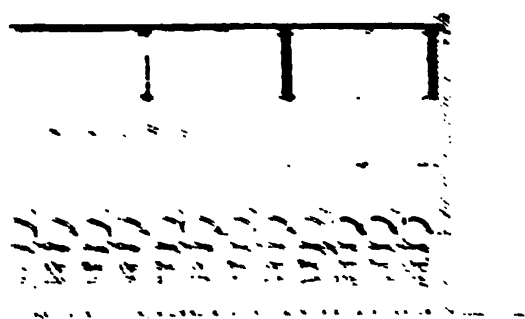
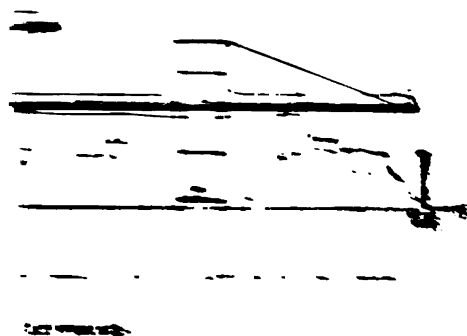


Figure 1. Schematic diagram of the valve.

together without either operation in any way influencing or interfering with the other. The load may thus be carried along the shortest trajectory from the point where it is picked up to that where it is delivered. The same machinery also gives complete

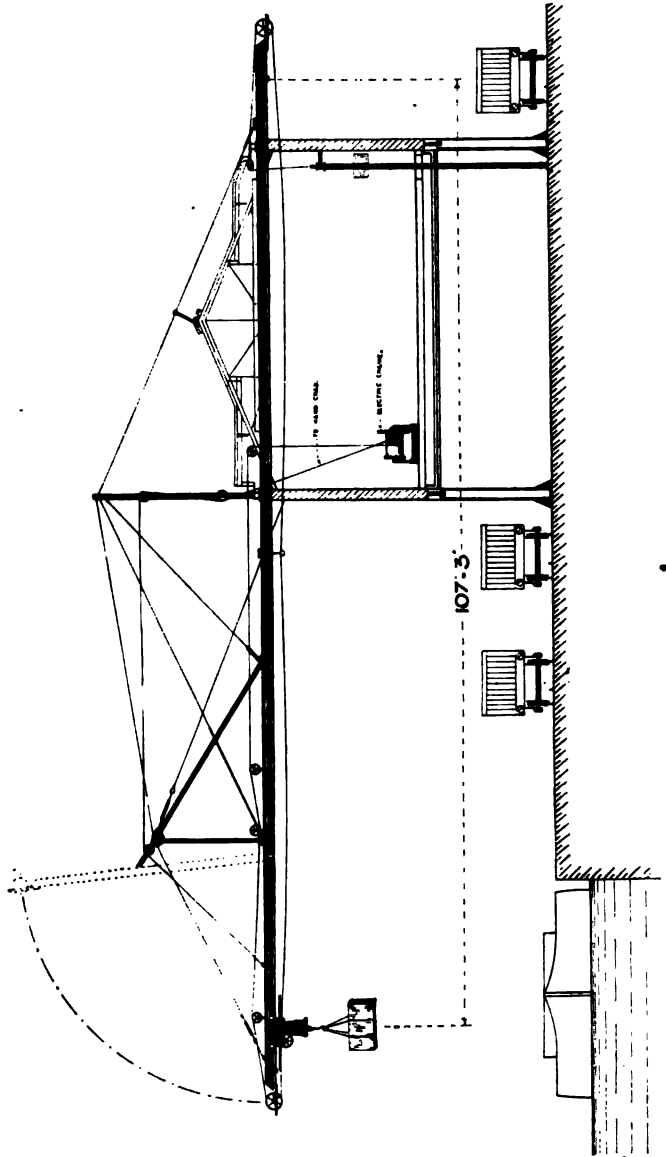


Fig. 698. Cross Section of Stores at the Royal Arsenal, Woolwich, showing Transporter for the Storing and Shipping of War Material.

command over opening and closing of the grab, these operations being effected either quickly or slowly in any desired position at the will of the operator. The grab may thus be lowered close down to the stock heap, and the material deposited with little breakage or dust. The hoisting or lowering and the transporting may be conducted at varying speeds, and the grab may be transported either open or closed.

Two electric travelling and slewing bridge transporters, built to the order of the Buenos Ayres Great Southern Railway for handling coal by means of automatic grabs at the freight terminus at Buenos Ayres, are illustrated in Fig. 700. All operations of the transporter are controlled by one driver from a platform on the tower, so situated as to command a good view of the work. An electrically driven hopper weighing machine travels along the bridge girder over the coal bunkers.

Temperley Portable Transporters are self-contained apparatus similar to

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Fig. 699. Temperley Fixed Transporters for Storing and Shipping Military Stores at the Royal Arsenal, Woolwich.

those already described, but intended chiefly to be used on vessels and operated by the ship's winch. They consist of automatic travellers of either the single purchase or the double purchase type; the usual beam on which the traveller runs, suspended from any convenient support, such as the ship's derrick or a span between the masts, and held in an inclined position of 1 in 3 by guys; and a lifting rope which is led to the ship's own winch for lifting, transporting, and lowering the load. For use on vessels the transporters are made from 30 to 65 ft. long, in multiples of 5 ft., and for loads up to 30 cwt.

Transporters of the M'Myler Co.—Transporters similar to those previously

described have been built by the M'Myler Co., of Cleveland and London, the difference being too slight to warrant a further description.

A small installation erected by this firm for the purpose of conveying the material from the ship to the railway truck is shown in Fig. 701. It is of interest chiefly on account of the unusual way in which the jib end of the transporter is disposed of when the latter is out of use. These ends are, as a rule, raised up out of the way, but in this case the end is lowered beneath the main structure into the position shown in dotted lines. This is accomplished by means of rope *d*. The rollers *a*, which are at the extremity of the jib end, move in the groove formed by two channel irons, which are bolted to the structure, the rope *b* remaining unaltered. This rope is guided in a similar manner to

Fig. 700. Two Temperley Electric Travelling and Slewing Transporters.

that shown in Fig. 689, but as this transporter works in conjunction with a two-rope grab, an additional rope is employed for the opening of the grab. Such installations are successfully at work on the Providence River, Indiana, U.S.A.

Brown Hoist Transporters for Jones & Adams, West Superior, U.S.A.—This installation is illustrated in Figs. 702 and 703, which give plan and elevation of the cranes; it consists of three Brown bridge tramway cranes, operated by electric power. The three transporters are shown running side by side on the same lines of rails, and are used for unloading coal from vessels and conveying it to stock piles or into railway trucks. The capacity of three of these transporters is about 2,500 tons of coal in ten hours. The average capacity is, however, 60 tons per transporter per hour, or one trip per minute.

The grab used is of a capacity of 1 ton, and a test was made with Hocking coal,

which is one of the most lumpy coals in the United States, and more resembles Scotch coal. Every bucket of coal was carried from the front of the quay to a distance of about 150 ft. before the grab was allowed to discharge. The illustration renders a minute description unnecessary. The transporter is manipulated from a machinery house which has a driver's cabin above, and can move backward and forward along the quay side over the three lines of rails shown. The grab is lowered into the hold, and when full, raised again, and the coal or other material is brought over the stock pile or over railway trucks, where the grab is opened to discharge its load. The same installation can, of course, be used to take the material from the stock pile with the grab, and discharge it into either railway trucks, or into vessels at the quay side. This installation was erected by the Brown Hoisting Machinery Co.

Bleichert's Transporters.—The transporter illustrated in Fig. 704 consists essentially of a bridge girder *B* with two extensions *A* and *A*¹, and two trestles *P* and *S*

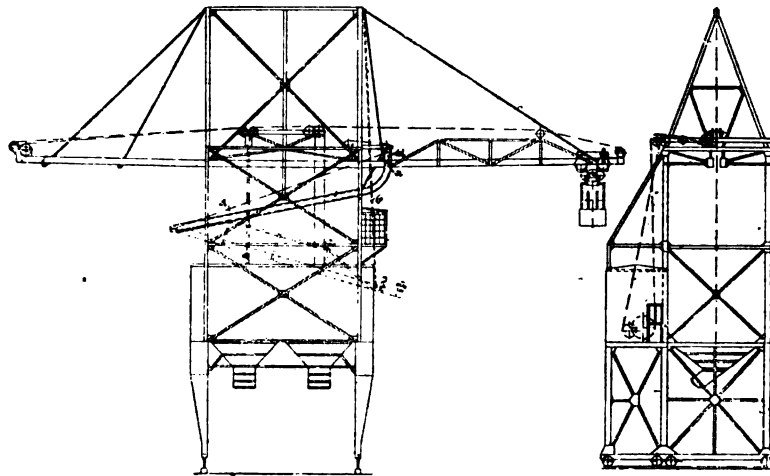
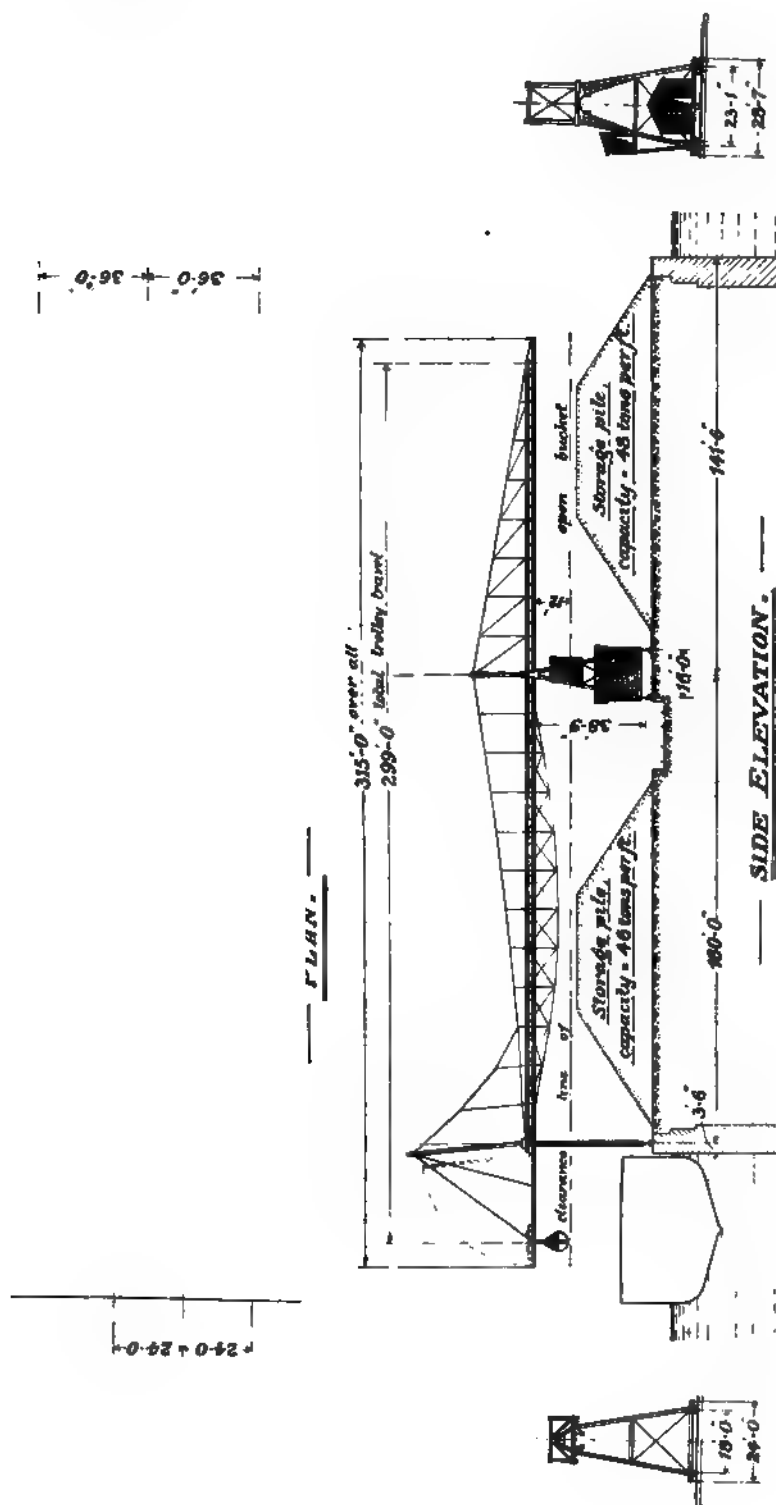


Fig. 701. Transporter of the M'Myler Co.

both mounted on wheels. The bridge or gantry is designed for the sole purpose of supporting the running head with its load. The main support *s*, which also encloses the motor-house, rests on two lines of rails. The trestle *P* on the quay side is very light in comparison with the main support, and is so coupled to the gantry that it gives sufficiently to make allowance for any expansion or contraction of the bridge through a change of temperature. The extension *A* is so hinged that it can be moved out of the way of the ship's tackle as shown by dotted lines. It can be raised by the small winch *w*, and lowered by its own weight and by the use of a brake. The skip, which runs the whole length of the gantry, can be unloaded either into a stock heap or into railway trucks, as may be seen from the illustration. Two independent ropes are used for the manipulation of the transporter, the one for lifting and the other for conveying. The action is as follows:—The skip, after being filled in the ship's hold, is raised to its fullest extent, so that the fall-block engages with the traveller, whereupon the lifting rope has no further load to carry. The conveying rope is then brought into action, and the traveller with its load is brought to the discharging point and there tipped. As the plant is mounted on wheels it can be moved forward or backward to discharge



Figs. 702 and 703. Plan and Elevation of Transporters Erected for Messrs Jones & Adams, West Superior, U.S.A.

the ship without altering its position. The operator's cabin, marked *H* in the illustration, is so placed as to give a good view of the unloading operations.

The time occupied by one skip in travelling from and returning to the ship is about one minute. The contents of the skip weigh $1\frac{1}{2}$ tons. In order to avoid any loss of time several skips are always in use. The average capacity is 500 tons in ten hours. This, of course, depends very much on the number of trimmers who fill the skips, and the nature of the material to be unloaded. It would be increased if a grab were used instead of the ordinary skip.

A transporter, also by Bleichert, which is similar to the one already described, but is much shorter, is illustrated in Fig. 705; it is only used for unloading ships into railway trucks. The bridge or gantry *AA* is supported by two uprights *P* at a sufficient distance apart to allow room for two lines of rails. The steam engine and boiler are shown in the illustration, and their weight gives additional stability to the structure. The jib end of the bridge can be raised in a similar manner to that of the one previously described, and the action of the machine is very similar. The capacity of any of these transporters can be doubled by having two sets of rails for two travellers on the same gantry.

Fig. 704. Transporter by Bleichert.

Transporter Erected at a Berlin Gasworks.—A transporter in conjunction with a steel band conveyor is illustrated in Fig. 706.

This plant was built by Pohlig, and consists of the ordinary type of "Hunt" transporter in conjunction with a grab. The coal, after being unloaded from the barge, is deposited into a hopper, from which it is admitted to the steel band conveyor, which takes it to the gasworks.

Transporters at the Coal Store of the Danish Coal Co., Copenhagen.—Fig. 707 shows an installation for the Danish Coal Co.'s store at

Copenhagen, in which may be seen five transporters of this type which unload the coal into a store.

Transporters at the Zürich Gasworks.—A similar installation erected by the same firm, in which three transporters are working side by side, is illustrated in Fig. 708.

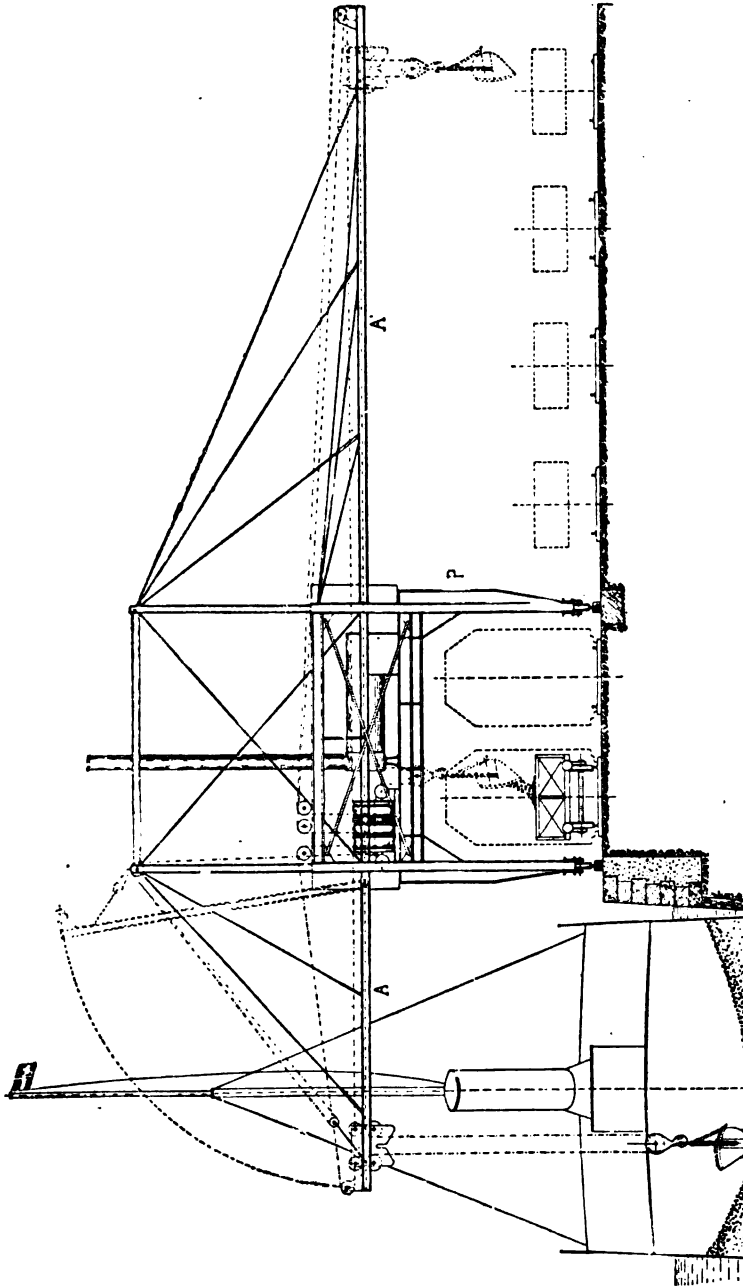


Fig. 705. Transporter by Bleichert.

This is the coal-receiving installation for the gasworks, Zürich, Switzerland. After the coal has been received by these transporters, it is deposited in the cars of the "Hunt"

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Fig 706. High-Level Crane at a Gasworks, Berlin.

automatic railway. One of these is shown in the illustration just starting on its journey to the coal store.

Transporter of the C. W. Hunt Co. — A transporter of the most recent and improved type is that designed by Messrs C. W. Hunt Co. for the Lincoln Wharf Power Station of the Boston (U.S.A.) Elevated Railway Co., which is remarkable for its enormous capacity. Bituminous coal is unloaded and raised to a height of 90 ft. above the water level from the hatch of the vessel, and delivered to the stock pile or into overhead bunkers above mechanical stokers. The coal is unloaded at the rate of 320 tons per hour by one transporter. The driving power is provided by an engine of 300 H.P. which also drives the coal-breaking machinery that forms part of the plant, and is for the purpose of breaking the coal into suitable sizes for automatic stokers. The capacity of the coal-breaker is 5 tons per minute. The grab in use with this transporter has a capacity of 2 tons with each lift, and the time occupied in raising the loaded grab to the overhead hopper is only six seconds. It is said that the whole cycle of unloading operations, including lowering the grab, running it out on the jib, opening it, filling it by its own action with 2 tons of coal, raising it again and discharging it, can be performed in twenty-two seconds. The crane is mounted on wheels, so that it can be adjusted to the

Fig. 707. Coal-Unloading Plant of the Danish Coal Co., Copenhagen.

hatchway. The jib end of the crane is 40 ft. long, so that the grab can be run out to a sufficient length to take the coal from the hold of the largest ships.

Fig. 708. Coal-Unloading Plant in connection with Hunt's Automatic Railway at the Zürich Gasworks.

See also Hoover & Mason's Ore-Handling Plant, Chapter XXVIII, "Handling Raw Material in connection with Blast Furnaces"; and Chapter XLI, "Storing of Coal and other Minerals in Stock Heaps and Silos."

CHAPTER XXXII

UNLOADING VESSELS BY MEANS OF BARGE OR SHIP ELEVATORS AND MARINE LEGS

BARGE ELEVATORS

THESE are essentially bucket elevators as fully described in Chapter II., pages 10-25. They vary from those principally in the form of the elevator well, which is not entirely enclosed but frequently made of skeleton work, so that the material to be handled can enter freely. The driving arrangements at the upper terminal necessarily differ from those of an ordinary stationary elevator, as the position of the terminal in relation to the driving shaft is constantly varied as the quantity of material in the barge is lessened. With the more general use of electro-motors, these are frequently adjusted to drive and form part of the elevator head. Such elevators have also been made latterly to telescope, when the lower portion can be adjusted to accommodate itself to tide and cargo working without altering the position of the upper terminal, by the use of an adjustable bight in the endless chain of buckets. With regard to the suspension of the apparatus from the supporting structure, this must be effected in such a way as not to burden the top pulley spindle with the weight of the elevator.

The simplest form of support is that which allows of merely an up-and-down motion. Such an installation would, however, only be suitable for very narrow canal barges, as through inability to rack the appliance from side to side of the barge a great deal of cargo trimming would otherwise be necessary. The more usual method of support is to suspend the elevator from a jib-like steel structure in such a way as to allow it a pendulum-like or racking motion so that it can be made to reach from side to side of the barge. Either of the above methods is suitable for barges in non-tidal rivers and canals. For tidal rivers where the barges are frequently compelled to take the ground at low tide, so that they become stranded and therefore a fixture, barge elevators are frequently fitted for such purposes to the end of a jib-like steel structure which allows of their slewing sideways and being luffed. In the former case, applying to canals and non tidal rivers, the barges are so moored that the elevator descends into the hold at one end, and the mooring is changed as the cargo is removed. With the latter type, which allows of a slewing action, a greater reach is obtained to make up for the inability to move the barge when stranded.

Barge elevators are generally used in connection with granaries, flour mills, breweries, and oil mills, as well as at smaller gasworks for handling material of small and uniform size. Grain and seeds, such as cotton or linseed, as well as nuts and other small material, can readily be cleared out of a ship's hold by lowering the elevator into the bulk of the material to be conveyed, when it will feed itself. All that is required on the part of the driver is to keep lowering the elevator as the vessel is cleared.

For larger material barge elevators are subject to the same limitations as ordinary bucket elevators in regard to handling material containing larger fragments. Barge elevators may either be supported from the factory building itself, from the end of a

steel gantry, or may be arranged portably on wheels to run along the quay wall ; this latter method also overcomes the difficulties mentioned above for unloading stranded barges.

For large capacities, say 40 tons per hour and over, pneumatic grain elevators are coming into more general use, owing to the great advantage of saving trimming expenses, although on the other hand the driving power consumed is considerably greater than that for bucket elevators.

Fig. 709. Spencer's Barge Elevators at the Wharf of Messrs J. Dudin & Sons, London.

The following examples are grouped under three heads: **Stationary, Portable, and Floating Barge Elevators**, these latter being sometimes called Marine Legs.

STATIONARY BARGE ELEVATORS

Spencer's Barge Elevators.—These are of the types already outlined, and are so well known that they need very little description. A typical installation is that erected at the wharf of Messrs J. Dudin & Sons, London, where three such elevators are at work (see Fig. 709). They are made with steel casings and have each a capacity of 30 tons per hour. Each elevator is supported on the jib by means of spring hinges,

which are sufficiently flexible to prevent any damage to the elevators from any side movement which might be caused by the traffic in the river during their use. They were built by Spencer & Co., Ltd., of Melksham.

Barge Elevator for Coal, in conjunction with a Zimmer conveyor, for the



Fig. 710. Barge Elevator for Unloading.

Tonbridge Gasworks, is illustrated in Fig. 710. The full lines show it in working position, whilst the dotted lines show it at rest, and placed out of the way of the canal traffic. The elevator is lowered into one end of the barge to be emptied, and the coal is trimmed into the elevator well by shovels, and as the barge is emptied its position is altered, as described. The elevator at the top terminal delivers its load by means of a hinged shoot into a Zimmer conveyor, which distributes the coal over the store

by a number of outlets. The elevator is suspended at a point 6 ft. below the top spindle on a steel beam 16 ft. long, which has a balance weight at the other end to equalise the weight of the elevator.

This mode of fixing has the advantage that the elevator can be moved round its support and swung into any position across the width of the barge. The winch on the supporting column controls the raising and lowering of the elevator.

A barge elevator for grain, small coal, etc., would be arranged as shown in the

Fig. 711. Further Type of Barge Elevator.

illustration, with the exception that the elevator base has no inlet spout, but is of open construction, to admit the grain to the elevator well to be received by the buckets.

A similar design of a barge elevator feeding a band conveyor is shown in Fig. 711. The elevator itself is driven from the conveyor, the latter receiving its motive power at the opposite end. It is suspended by two steel ropes; one end of each can be wound upon one of two drums, on either side of the elevator casing. The hand wheel A controls the gear for lowering and raising. This is effected by means of power obtained from the band terminal. Each drum is fitted with a worm and worm wheel. The elevator must

always be in a perpendicular position, and is there maintained by four small guide rollers which prevent any side movement, but allow of an up-and-down motion.

As the rise of the elevator is only a few feet, owing to the barges being shallow and there being no tidal variation in the river, the gearing of the band to the elevator is in no way detrimental to the arrangement, for even if the elevator and band are at their highest points the efficiency of the latter is not in any way impaired.

The whole of this installation is equally suitable for unloading grain, etc., with the slight modification at the elevator well already mentioned.

Barge Elevator for Grain in Connection with Granary at Dresden-Riesa, on the River Elbe.—This installation is unique, and varies from those previously described. Firstly, it was impossible to erect the receiving terminal close to the quay

Fig. 712. Perspective View of Barge Elevator and Granary at Dresden-Riesa.

wall, owing to the portable cranes of the Harbour Authorities having to travel in front of it; secondly, the grain had to be conveyed a great distance to reach the warehouse, there being no site available nearer the quay. As a matter of fact the distance the band conveyor has to deliver from the edge of the quay wall to the granary is 812 ft., and the raised gantry which encloses the band traverses fifteen lines of rails and three roads.

A good general idea of the installation is given by Fig. 712, which shows the suspended barge elevator with the jib containing the first band conveyor. It also shows the small structure in which the grain is freed from dust, and the iron gantry in the distance leading to the granary. Fig. 713 represents a view of the receiving end at the river side which overhangs the two lines of rails along the quay wall. The barge elevator is driven by a 15 H.P. electro-motor mounted on the top of the elevator itself, which also drives the band conveyor in the jib.

The foundations for the terminal at the river side are 36 ft. deep owing to the poor

condition of the ground, the very heavy load, and the length of the jib, which latter is sufficiently long to reach over one into the middle of a second ship to unload it. The main band conveyor which communicates between the small structure on the gantry—already mentioned—and the granary, is led over four drums at the river side terminal to keep the two runs of the conveyor sufficiently far apart to get a clear delivery for the grain from the lower run of the band, as both strands are used for conveying to and from the warehouse; the other terminal in the granary is led over three stationary drums and one loose one for tightening; this terminal with its driving motor is shown in Fig. 714.

There is also a third band conveyor working on both the upper and lower run which connects the main band with that in the jib, and which also takes the grain from the main band *via* an elevator in the small structure to a long loading shoot which delivers

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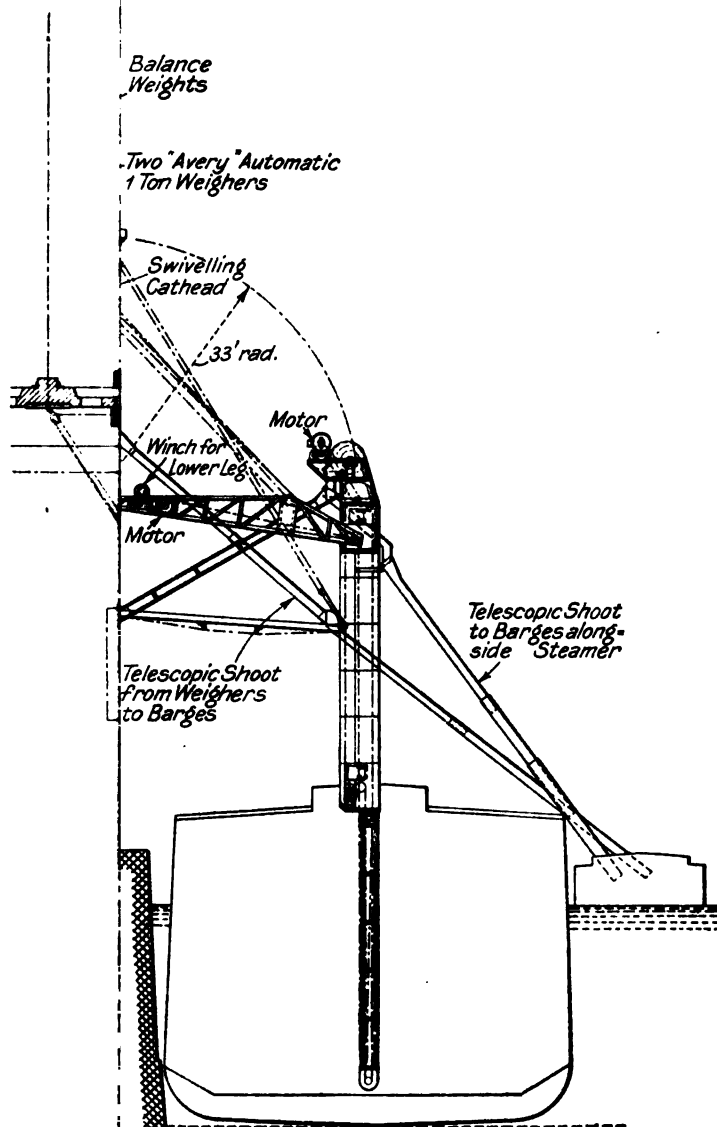
Fig. 713. Side View of Barge Elevator for Grain.

the grain into barges. The capacity of the installation, which was built by the Seck Engineering Co., of Dresden,¹ is from 50 to 60 tons of grain per hour.

Barge Elevator at the Waterloo Dock, Liverpool.—Another most interesting and up-to-date elevator of the stationary type is that erected at the Grain Warehouse of the Mersey Dock and Harbour Board, Waterloo Dock, Liverpool. It is illustrated in Figs. 715, 716, and 717, which represent not only the external barge elevator, but also the handling devices (with which we are not here concerned) which receive the grain from the barge elevator.

The whole of the plant is electrically operated, and it is interesting to note how motors have been introduced for the driving of the bucket elevator and for the raising and lowering gear. It will be seen from the illustrations that the elevator is fitted with a telescopic arrangement whereby the receiving terminal can be raised or lowered in

¹ From an article by W. Spielvogel in the *Zeitschrift des Vereins deutscher Ingenieure* of 20th September 1913.



oard, Waterloo Dock, Liverpool.

[To face page 490.

accordance with the depth of the barge or of the vessel to be unloaded. The whole elevator is also so supported that further limits of travel up and down are obtainable by the movement of the latticed girder supporting arm, which is pivoted at its outer end at the elevator head, and at its inner end on the wall of the building. This elevator is 45 ft. long and can be extended to 77 ft. by means of a bight operated by an electric winch.

It will also be noticed that the telescopic elevator is provided with three motors. One of 22 H.P. crane rated capacity carried on a suitable support at the elevator head, whence it drives the chain of buckets through gearing; the second motor of 13 H.P. crane rating is fixed at the warehouse end of the movable girder arm, supporting the elevator proper, and driving a small winch which serves to raise and lower the telescopic leg; the third motor, crane rated for 10 H.P., which drives a winch through gearing, is used for raising and lowering the latticed girder arm. To maintain an even load on this

Fig. 714. Driving Gear of Receiving Band Conveyor.

motor, the arm carrying the telescopic elevator is provided with a counterpoise system in which is included a method of balancing which ingeniously adjusts the balance weights according to the particular position of the telescopic elevator. It is clear that at the lowest limit of its travel the elevator will require full balance weights, and the opposite will be the case for the upper limit. When less counterbalance is necessary the weights concertina together. The side elevation shows how the grain, after being raised to the elevator head, is disposed of in the building. Conversely the equipment provides telescopic shoots which admit of the loading of barges, either from the building itself or by means of the telescopic elevator from one barge to another, or from a large vessel to a barge alongside.

The designers of the equipment have provided a slewing machine which is operated by hand and admits of the travel of the telescopic head towards the building in either direction in order to bring the elevator closer in for operation from vessels close against the dockside. This slewing gear is actuated by a separate winch, and as it is only occasionally used, this winch is designed for hand movement. The equipment has been

attached to an existing warehouse without structural alterations, and has a grain handling capacity of 120 tons per hour. The manufacturers of the plant are Henry Simon, Ltd., Manchester.

PORTABLE BARGE ELEVATORS

These are very similar to the elevators attached to factory buildings and gantries for the purpose of clearing grain, coal, and similar materials from ships' holds. As

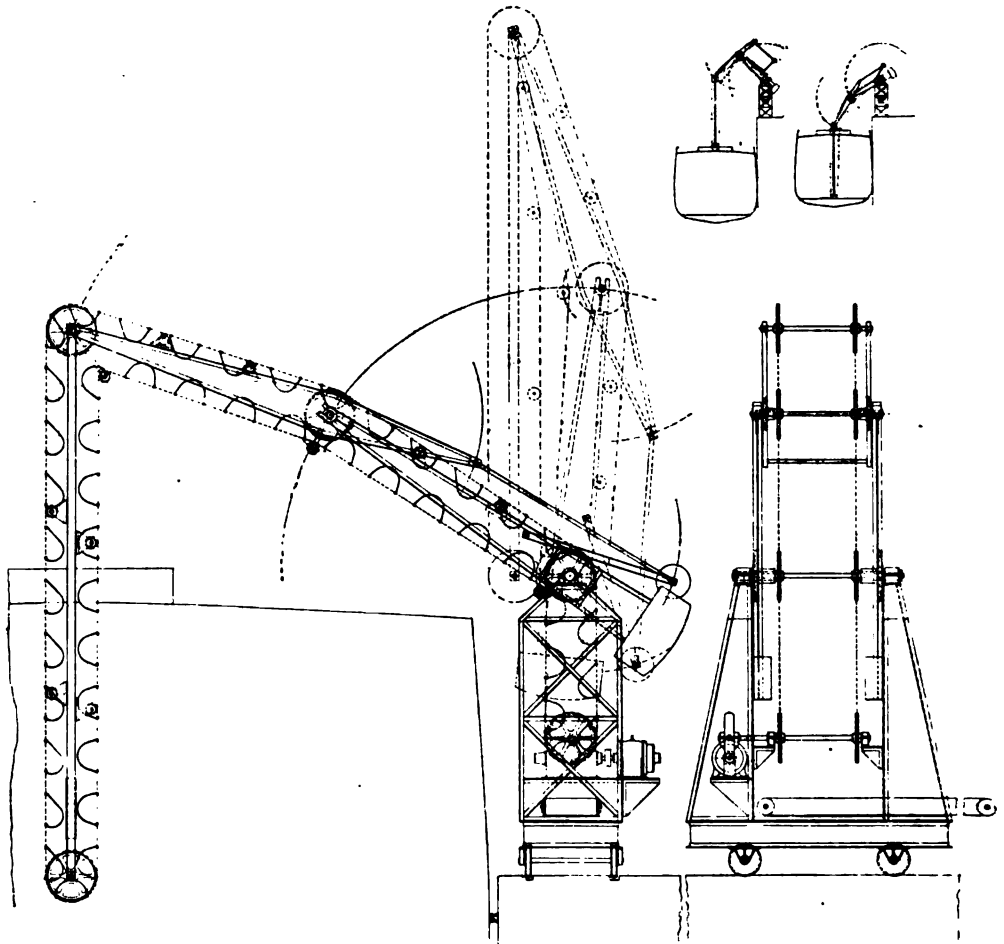


Fig. 718. Banana Unloader.

has previously been explained, they can only be used for coal when it is of a fairly uniform size.

Banana Unloader.—An elevator on similar lines to the Mitchell Cantilever Grain Elevator (described later) is shown in Fig. 718. It is adapted for travelling along a quay, and unloading bulk goods such as bananas, meat carcasses, etc. At the lowest position of the delivery terminal the bananas are dropped on to a band conveyor. This illustration particularly shows the extraordinary adaptability of the two levers in reaching from an extreme height to an extreme depth. The dotted lines show the apparatus

in the housed position, and the two smaller views indicate the two extreme working positions.

Banana Carriers for Loading and Unloading Vessels.—The carrier shown (Figs. 719 and 720) was installed for the United Fruit Co. in 1903, at the I. C. Ry. Co.'s Wharf, Mobile, Ala., under the patent rights of Messrs Edleston & Harris, by the Link Belt Co.

The machinery consists of canvas slings, attached to cross-bars between two endless chains in a manner to form pockets into which the bunches of bananas are placed, as shown. These pockets automatically adjust themselves to the direction of travel, and handle fruit without bruising or breaking the bunches. It is adjustable to depth of hold and height of tide.

Fig. 719. Carrier receiving Bananas in Hold of Vessel.

Fig. 720. Carrier depositing the Fruit on Deck.

A similar apparatus is in use at New Orleans. It consists of an endless belt carrying canvas pockets, and is so arranged that one end may be introduced into the hold of the steamer through the hatchways, and the other situated contiguous to the railway trucks. The band is kept in a continuous slow motion by an electric motor. The bunches of bananas are taken from the ship's hold, laid in the moving canvas pockets, and then elevated and conveyed to a point opposite the door of the railway truck, where they are removed and hung or piled in the truck for transport.

Before the introduction of these labour-saving appliances, the bunches of bananas were carried from the ship by labourers, a large number of whom were employed for this purpose. In raising the bunches on to their shoulders, and in carrying them along a rather uneven way from the ship to the wharf and thence into the truck, a good deal of the fruit was damaged, and the bunches themselves were frequently jammed and

disfigured. The present method, in addition to assuring the transfer of the fruit from the ship to the cars in thoroughly good order, results in the saving of a notable amount of time and labour.

Barge Elevator for Grain.—A typical example of a movable barge elevator is that at work at the Eagle Oil Mills of J. Rank, Ltd., Hull, and which was built by Spencer & Co., Ltd., Melksham. It is driven by electricity, is self-propelling, and capable of raising 60 tons of seed per hour. The whole of the machinery for operating the elevator is erected in a corrugated iron cabin, which is movable with the elevator on the track. Travelling gear is provided in order to minimise the necessity of trimming as much as possible, as at low tide these barges lie on the mud, so that it would not be possible to move them for unloading purposes. The elevator delivers in any position of its travel through a telescopic shoot on to a

Fig. 721. Unloading Device with Barge Elevator.

band conveyor, carried on a gantry, which afterwards discharges through a suitable spout into the mill.

The electric current is conducted along the face of the warehouse wall, which is fitted with a number of wall plugs, from any of which a connection can be made by flexible cable to the motor.

A Barge Elevator by Unruh & Liebig, Leipzig, is shown in Fig. 721. This is very compact, but is only suitable for quay sides where no attention need be paid to the varying tides. It is driven by an electro-motor, the cable which supplies the current being concealed in a leather tube to allow the truck the necessary latitude in its movements on the quay. The hopper which receives the grain is fitted with an automatic weighing machine.

Travelling Grain Elevator at Avonmouth Docks.—This installation was erected by Spencer & Co., Ltd., of Melksham, for the Bristol Docks Committee at the Avonmouth Docks.

The elevator was designed for a capacity of 75 tons per hour, but was proved on test capable of taking from a vessel's hold rather more than 100 tons of grain per hour. It is built on the balanced lattice girder principle, and has double elevator legs so arranged as to operate on both sides of the steamer's shaft-tunnel or cargo-parting boards,

Fig. 722. Ship Elevator at Avonmouth Docks in Housed Position.

thus considerably reducing the cost of trimming. The whole structure is mounted on eight wheels, having a wheel base of 20 ft., and arranged to run on rails laid down at 12 ft. gauge. Hand gear is fitted to these travelling wheels in such a manner that the whole apparatus may be shifted by means of manual labour.

The elevator itself stands 100 ft. high when housed, and is capable of unloading

vessels up to 55 ft. beam. It is so constructed as to lift the grain from any level within a range of 25 ft. below the coping of the quay, and to rise clear over the vessel's hatches when such are 22 ft. above the coping edge, thus having a total range of travel of no less than 47 ft. up and down.

The elevators are fitted with buckets 13 in. wide which are pitched 12 in. apart.

Fig. 722 shows the elevator in a housed position when not in use.

Fig. 723 shows it at work taking grain from a vessel's hold and delivering to the granary alongside. The total weight of the whole apparatus is between 90 and 100 tons, and there are no less than 18 tons of balancing material used in the back end of the lattice girder.

This installation is driven by electro-motors, one motor being provided to drive the

Fig. 723. Elevator at Avonmouth Docks when at Work.

elevator and the receiving band conveyor, which is connected therewith, also the controlling hoist. Another motor is provided for driving a set of power trimming gears used for trimming the grain to the elevator.

A band conveyor attached to the lattice girder conveys the grain from the elevator by telescopic shoots to the transit shed alongside. The trimming gear for feeding the grain to the elevator in the vessel's hold consists of four large wooden grain trimming shovels or ploughs, driven by a suitable winch from an electro-motor.

The plant¹ proved so satisfactory that the Docks Committee ordered a similar but larger installation for their grain docks in Bristol.

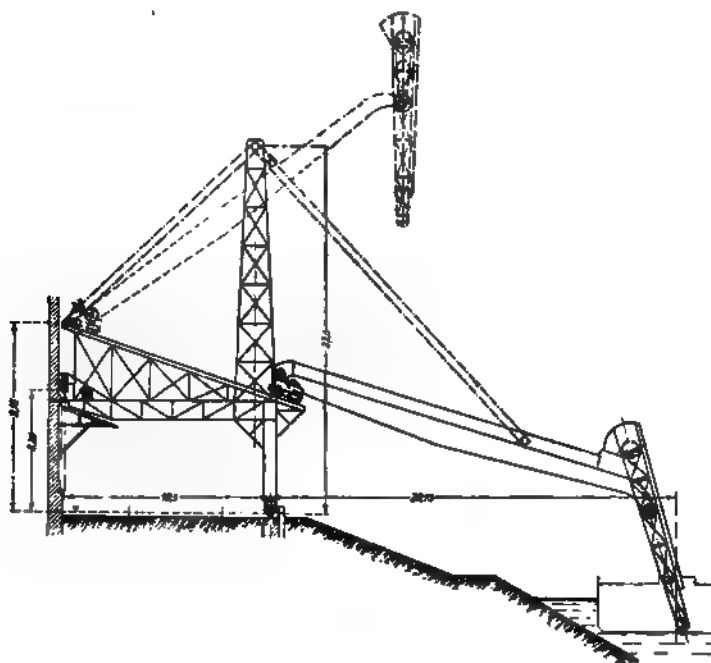
Barge Elevator for Handling Sacks.²—A somewhat more complex device

¹ *Milling*, 8th June 1903.

² From an article in *Zeitschrift des Vereins deutscher Ingenieure*, 30th November 1912.

is for the unloading of goods in sacks from barges to warehouses. Such installations are more especially for seeds, grain, etc., which are more generally handled in sacks, such as Indian corn, some oil seeds, nuts, flour, coffee, peas, lentils, salt, moist sugar, cement, etc.

Hitherto such goods have been unloaded by intermittent appliances such as cranes, mono-rail telfers, or other elevated devices manipulated by chains or cables, which have the decided disadvantage of causing waste of time waiting for the return of the empty receptacles for the next load; this is unavoidable with all intermittent methods of handling. The first installation to solve the problem of unloading such goods in a continuous operation, similar to the handling of bulk goods, was erected on a quay on the Danube at Vienna in 1910-11.



Figs. 724 and 725. Barge Elevator for Handling Goods in Sacks.
(The dimensions are in metres.)

Sacks have been conveyed for years by band conveyors on the level or on slight inclines, so that this part of the present installation presents no novelty; what had hitherto been unknown was the use of an elevator in combination with such band conveyors.

The elevator consists essentially of the usual upper and lower terminals with two chains, which are transversely connected at intervals by cross bearers upon which the sacks stand. The elevator is slightly inclined, and the space between the chains is fitted with a wooden back against which the sacks lean and slide during their ascent.

Figs. 724 and 725 show the general arrangement of the unloader, whilst Fig. 726 shows the relative position of the unloader to the warehouse. It will be seen from these illustrations that the bank of the Danube is at a gentle incline, and although there is no tide the water level varies considerably at different seasons of the year. The sloping bank makes it imperative that at high water the barges to be unloaded shall come nearer

to the warehouse. It is thus necessary to have the jib which receives the sacks from the elevator supported on the land side on a movable carriage which travels up on an inclined path, so that the relative position of all parts shall be the same for varying water levels.

The unloader is portable to reach the different holds of the large Danube barges. It travels at a speed of about 3 ft. per minute, and the height of the tower carrying the jib is 22 metres or 72 ft.

The *modus operandi* is as follows: A gang of men place the sacks upon the receptacles of the elevator, which deliver them on to the belt conveyor in the jib (for details of this see Figs. 727 and 728). Inside the receiving shed, and parallel with the inclined part of the land support of the jib end, is a second band conveyor which removes the sacks from the first one, and deposits them through one of the windows into the warehouse, where a similar elevator receives them and delivers them at the top of the building, there to be disposed of, by sliding and spiral shoots, all over the warehouse, or into carts and railway trucks. The elevator inside the building is so arranged that by the removal of a portion of the back board of the elevator the sacks may be delivered on any floor.

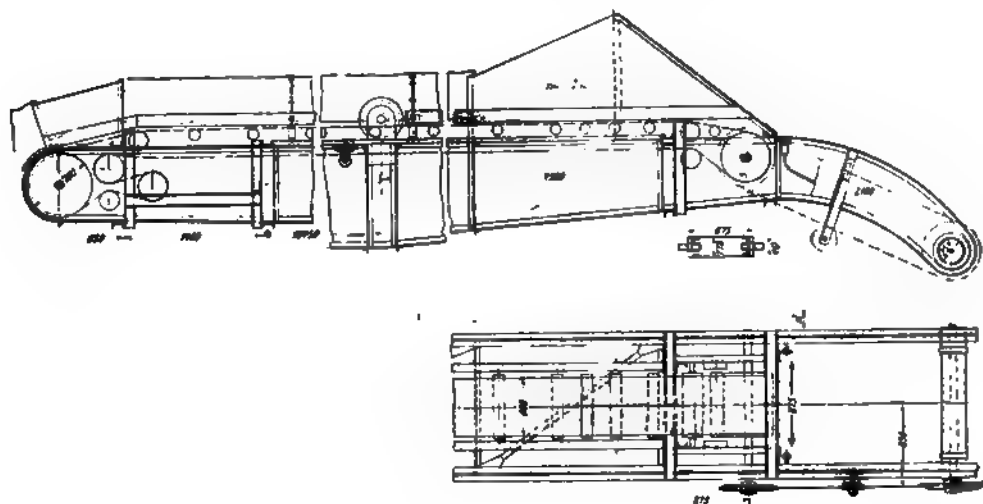
Electricity is the driving power used and is supplied by an 8 H.P. motor for the travelling gear, the winding tackle for raising the jib end up its inclined path if necessary, and also for driving the second

band conveyor. The second motor is of 5 H.P. and manipulates the sack elevator and the band in the jib. Five hundred or six hundred sacks of 160 lb. each are handled per hour.

Fig. 726. Warehouse for Storing and Handling Goods in Sacks.
(The dimensions are in metres.)

This installation has now been at work for a sufficient length of time to be pronounced a complete success, and the cost of unloading has been reduced by it to one-third of the cost of the hand labour previously employed.

Portable Barge Elevator for Grain.—A device which is portable in more than one sense is worth mentioning on account of its unique construction. It is built by Mohr & Federhaff, and consists of the usual barge elevator, to the delivery end of which is hinged a worm in a tubular casing. The latter is arranged telescopically so that a portion of the casing may be withdrawn and thus form a shoot for the delivery of the grain as it leaves the worm (the whole being in an inclined position). Fig. 729 shows this device suspended from the hook of an ordinary crane in the lowest position, so that the worm which receives the grain from the elevator just reaches a portable sacking apparatus for filling it into sacks. For high tide and bigger ships the whole tackle is raised by the crane, when the telescopic worm casing extends automatically. The worm does not then reach the entire length of the tube, but in that position the incline is



Figs. 727 and 728. Jib with Band Conveyor for Handling Sacks.

(The dimensions are in millimetres.)

sufficient for the grain to fall by gravity down to the end and deliver as before. When the crane is to be used for ordinary goods, the whole apparatus is closed up and deposited in a stand erected for it somewhere on the quay out of the way, but yet within reach of the crane. An electro-motor is fitted to the elevator head, geared by spur wheels to the elevator spindle, and from this by chain on to the worm.

The obvious advantage of such an installation for small ports is its low initial cost, as the same crane can be used for ordinary cargo as well as for unloading grain in bulk. It has also the further advantage that the unloading device, being suspended with its motor from a hook on the crane, is exceedingly flexible, so that almost all points of the ship's hold can be reached, which reduces trimming to a minimum. The capacity of this device is 40 tons per hour.

The housing of the device is fairly simple. By means of the hand wheel and chain *a* and *b*, the worm is raised sufficiently to disengage from a portable weighing house, when an auxiliary electric winch on the crane shortens the rope *c*, so that the telescopic worm closes up till it is home in position *d*, where it is held closed by an automatic

catch. If rope *c* is now slackened the worm drops close to the side of the elevator and the whole apparatus can be swung out of the way and housed till required for future use.

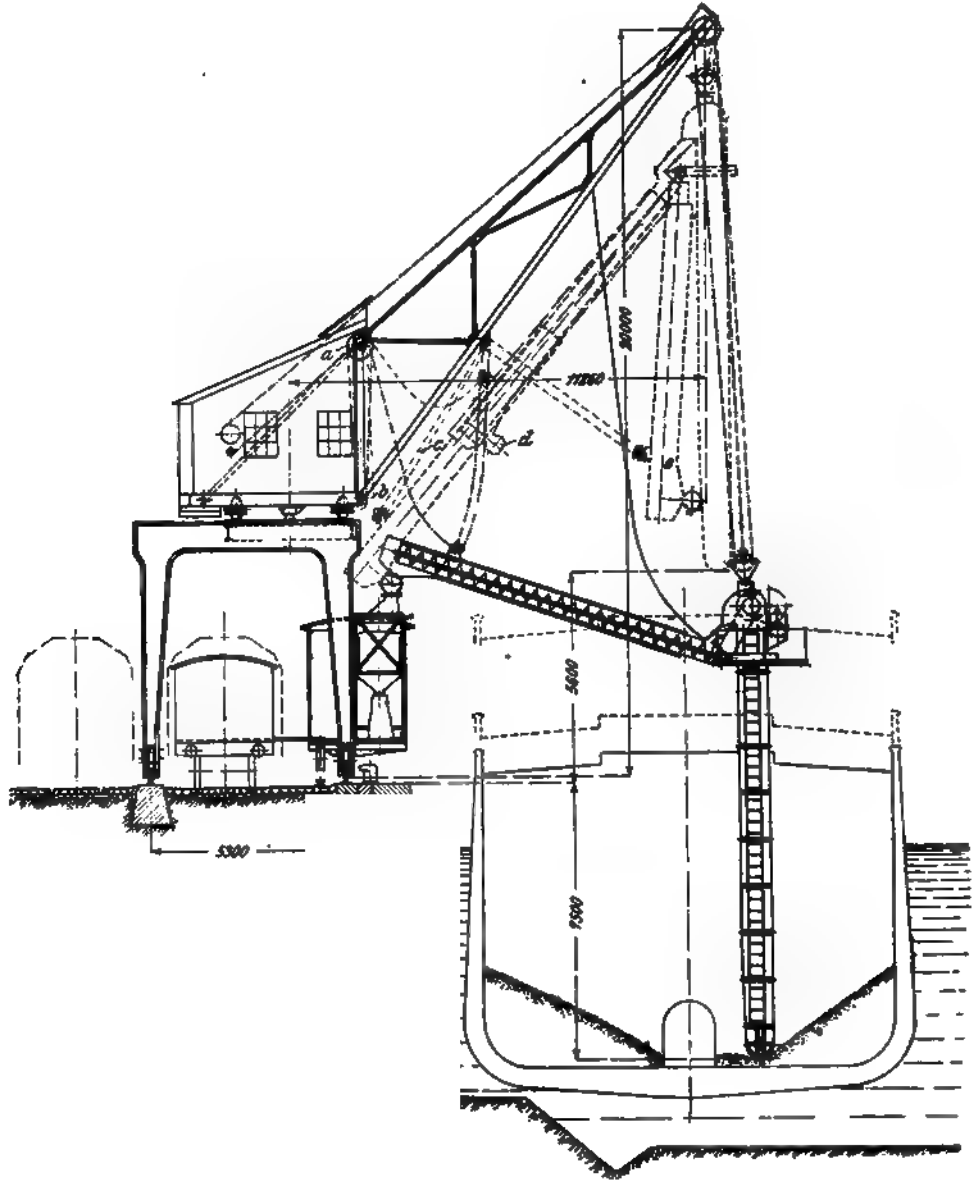


Fig. 729. Portable Barge Elevator Suspended from Hook of Ordinary Crane.
(The dimensions are in millimetres.)

The Mitchell Cantilever Grain-Discharging Elevators at Dunston-on-Tyne.—The Co-operative Wholesale Society, Ltd., have installed, in connection with their flour mill at Dunston, two large ship-discharging elevators of an unusual design (see Fig. 730). These elevators are the last link in a chain of improvements and develop-

ments which have been carried out in connection with this establishment. Formerly the whole of the foreign grain required for their mills had to be discharged at the docks lower down the river and from thence brought by steam barges to the mill at Dunston. In order to save all the expenses of storing and handling large quantities of grain several times, the Directors decided to put up a most complete plant for discharging and storing large cargoes of wheat. At the jetty on the eastern side of the mill steamers up to 7,500 tons can lie alongside at any state of the tide and by means of the two elevators a very quick delivery can be effected. The elevators were designed on the principle

Fig. 730. Two Travelling Ship Elevators at Dunston-on-Tyne.

of Mr A. H. Mitchell, the bulk grain engineer of the Port of London Authority. They are the first of the kind which have been erected as travelling elevators on shore, the Mitchell Patent having been more especially used in connection with floating elevators.

One of the chief points to be borne in mind in designing the installation was the rise and fall of the tide (20 ft.). The essential feature of these unloaders is that the jib, which supports the elevator, is not in a fixed position, and owing to an ingenious arrangement of balance weights the jibs can be moved backward or forward, the effect being that the elevator can be worked in a vertical position and still reach all parts of the ship's hold. For instance, when working in after-holds it is possible by tilting the jib post forward for the elevator to reach over the further side of the shaft tunnel and still remain in a vertical position. The same applies when working on the near side.

The unloaders are carried on strong underframes with long wheel bases ; four wheels at each end are provided and connected to an electro-motor, so that the apparatus can travel along the jetty to reach any hold of the ship.

The top of the balance post, carrying the jib, is 35 ft. above the jetty, so that the combined movements of the jib and post make it possible to take the elevator out of the holds of the largest ships bringing grain to this port, even at high water. The elevator is telescopic and can be extended to a length of 73 ft., so that the movements of the ship as it varies according to the tide can readily be followed by the elevator. After a steamer is once moored alongside it is not necessary to move it until the cargo is discharged.

Another important feature is that the elevators may be turned round on their bases by a small electro-motor, so that when they are not at work they may be housed entirely over the jetty so that there is no portion projecting over the river. The elevator buckets deliver through an automatic telescopic shoot on to a band conveyor which has been erected within the jib and is therefore protected from the influences of the weather. The grain is then delivered by another shoot to a band conveyor which runs along the quay. There is a total absence of long driving chains, as there is an electro-motor for each motion. The motor for driving the elevator is fixed on the top terminal and drives direct by gearing. A separate motor is provided to drive the belt conveyor and also for each of the motions, travelling, turning, jib controlling, post tilting, and for raising the telescopic elevator, in all seven motors for each unloader.

On the side of each appliance is the driver's cabin, which is placed at such a height that the driver has a good view of the hatchway in which the elevator is working. The switchboard is in the cabin as well as the other gear in connection with the electric installation. The whole is so well arranged that one man can take the elevator out of one hold, travel to another hold, and start work again without any assistance.

The guaranteed capacity of each elevator was 100 tons per hour, but from the first that quantity has been considerably exceeded, 120 tons being easily handled. During the first few weeks of working, several cargoes of grain amounting to over 40,000 tons were discharged most satisfactorily. As an instance of quick dispatch it may be mentioned that a cargo of 7,500 tons of wheat was discharged in less than five days. The installation was built by Ammie, Giesecke, & Konegen, of Brunswick.

There are no practical reasons why installations similar to the foregoing should not be mounted on pontoons and thus be converted into floating barge elevators, as the mechanical arrangements are practically identical with those of the floating Mitchell cantilever elevator described later.

FLOATING ELEVATORS OR MARINE LEGS

Floating Derrick Elevator.—The derrick elevator erected for the late London Grain Elevator Co., now absorbed into the Port of London Authority, is also the invention of Mr A. H. Mitchell, engineer of the old company.

This derrick unloading elevator is shown in Fig. 731, which represents it ready to be lowered over the ship's side for unloading purposes.

It has been designed for unloading grain from the largest types of American liners engaged in the grain trade (such vessels as the "Minnehaha" and sister ships of the Atlantic Transport Co.) into lighters for conveyance into other coasting vessels or into warehouses.

The first elevator of this type was built by Spencer & Co., Ltd., of Melksham.

The whole plant consists essentially of four parts. Firstly, the pontoon; secondly, the travelling car, containing the engines and the various driving gears; thirdly, the

1

Fig. 731. Derrick Elevator ready to be Lowered over Ship's Side.

support, consisting of lattice girders and shear legs; and fourthly, the elevator itself which is lowered into the ship's hold. The pontoon is built of steel, and is 75 ft. long by 24 ft. wide, and has a draught of 8 ft. It is square at the bow so that it can be

brought close to the side of the vessel which is to be discharged. The deck of the pontoon is specially strong, and is fitted with a track, the rails of which run from bow to stern, and are 7 ft. apart. The travelling car moves on these. There are two vertical boilers in the stern, one being sufficient to drive the plant, the other only being used in case of emergency. Ample bunker space is allowed amidship.

The pontoon is self-propelling by means of a small marine engine and a pair of screw propellers. The space in the hold not required for bunker purposes is filled with ballast to ensure the stability of the vessel. The trolley, which is 17 ft. long by 9 ft. wide, rests on the rails on six wheels. The range of its motion from end to end is 36 ft. It is conveyed backward or forward by a pair of wire ropes which are fastened at one end to the pontoon and at the other end to the drums of the winches. The engine, which is in the centre of the trolley, is a 30 H.P. of double-cylinder type, and is connected with the boiler by flexible pipes, the connection being made in the centre of the revolving drum in such a way that the piping rolls itself on or off the drum as the trolley moves backward or forward.

The large lattice girders of the derrick shown in the illustration are carried on trunnions on the forepart of the trolley, while the main shaft, which drives the elevator and conveyors, passes through these hollow trunnions. In front of these is the gearing for raising or lowering the main jib, and the gearing for moving the elevator to a vertical position. The trolley is cased in, and forms the attendant's cabin, in which all the levers for manipulating the different parts are placed. The housing has been removed for the purpose of taking the photograph from which this illustration was prepared. The structure at its supports is formed of two pitch pine shear legs in the bow, one on either side, and a lattice steel back leg which is about 50 ft. long. These shear and back legs are connected together at the top by a steel pin and collars, the back leg being hinged to the trolley and the front legs to the deck of the pontoon. All these parts can readily be raised to any angle, allowing perfect freedom for the trolley to move backward and forward on deck. The elevator is supported by a jib which is hinged to the back leg, as shown in the illustration. On this jib is fitted a band conveyor 2 ft. 6 in. wide, which is necessary, as the elevator itself dips deep down into the ship's hold, and the grain may have to be conveyed up or down to reach its destination.

Just below the jib on the other side of the back leg extends a cantilever (also fitted with a band conveyor) projecting over the stern of the pontoon, at the end of which are two long shoots for the delivery of the grain. The buckets are 20 in. wide, and of the continuous type, similar to those illustrated in Figs. 15 and 16, page 19.

The elevator is 53 ft. long, it has a vertical range of 18 ft., and when in its highest position the head is 90 ft. above the water level, and has a clear 40 ft. between the elevator well and the water level; this is necessary to reach over the side of large ships. It can discharge grain from a ship with a 40-ft. beam and a hold 45 ft. deep. The driving power required is 20 B.H.P. and the capacity is 150 tons per hour, which can be kept up provided the trimmers can keep pace with it.

These elevators are in use at the Victoria and Albert and also at Tilbury Docks.

The elevator can be housed very neatly when out of use, in which case it lies flat upon the deck, and the delivery shoots are drawn in, so as not to project over the sides of the pontoon. The position of the shear legs is then approximately at an angle of 35° to the deck.

The expeditious way in which the marine leg can be set to work may be gauged from the test in which it was lifted over the bulwarks of a ship 30 ft. 6 in. above the

water level, lowered into the hold to a depth of 43 ft., and started to work delivering grain in seven minutes.

The Mitchell Cantilever Grain Elevator.—This is the best known and most efficient type of a floating apparatus which can unload a cargo of grain from the largest ocean-going steamer. As its development may be of interest, it is fully given here. It is, of course, only proposed to deal, in these introductory remarks, with the general arrangement for manipulating the machine, as the elevator itself presents no new features.

The earliest type was constructed as shown in diagram, Fig. 732. It consists essentially of a self-contained elevator suspended from a balanced rocking jib supported at the top of a stationary lattice steel post. The objection to this construction lies chiefly in the enormous top weight which necessitates a wide pontoon to ensure stability. This will be better realised when it is considered that in order to unload large ships with side beam the jib must be very long in order to reach to the side remote from the pontoon with the elevator leg; this necessitates very considerable balance weight. Such a machine also lacks facilities for adjustment; if, for instance, the elevator has to work on the near side of the pontoon it becomes necessary to warp the pontoon off the ship, and these not infrequent readjustments involve a considerable waste of time.

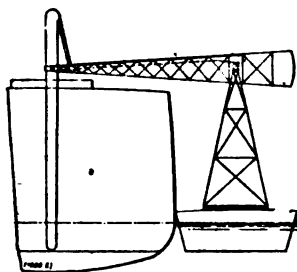


Fig. 732.

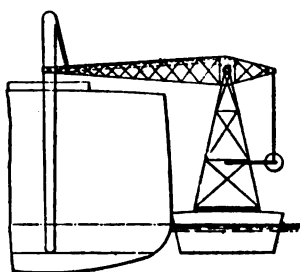


Fig. 733.

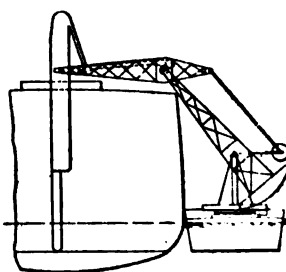


Fig. 734.

Diagrams showing Development of Mitchell's Cantilever Grain Elevator.

The first-mentioned defect of the top weight has been overcome by the construction shown in diagram in Fig. 733. In this case the elevator leg and its jib are balanced by a weight carried comparatively low down on levers pivoted at the centre of the post, these levers being of equal length to the back end of the jib, and the connecting link of such a length that jib and levers are always parallel; by such a parallel motion, the apparatus is in balance in any position. As the balance weight is now low down, a narrower pontoon may be employed and still give sufficient stability.

The second defect is overcome in a construction shown in the diagram, Fig. 734, which represents the final development of the present marine leg. It will be seen from the diagram that in addition to the first improvement the post itself is pivoted and balanced by a counterweight at its lower end.

It will be evident that in such a combination the centre of gravity of the jib and the balance weight, if properly balanced, must coincide with some point on the centre line of the crane post, and if the post be extended downwards the balance weight at the bottom of the post can be made to balance the other two weights and bring the centre of gravity of the whole to the centre of the fulcrum upon which the post rotates. This combined balancing is true, and can be maintained with a fixed load on the elevator. It is, however, upset by the addition of the load, but not to any serious extent.

In practice the elevator is allowed to slightly overbalance to allow it to sink into the grain, whilst the balance at the bottom of the post is rather overweighted to counteract any capsizing tendency.

The result of this combination of levers is to give an extraordinary range of motion to the elevator leg, and at the same time to allow practically no movement of the centre of gravity of the whole.

The elevator can, therefore, be placed upon a turntable and worked either side on or end on with impunity, and when required for towing can be turned right round and the elevator stowed upon the deck or rested upon the weigh-house, as shown in the drawings.

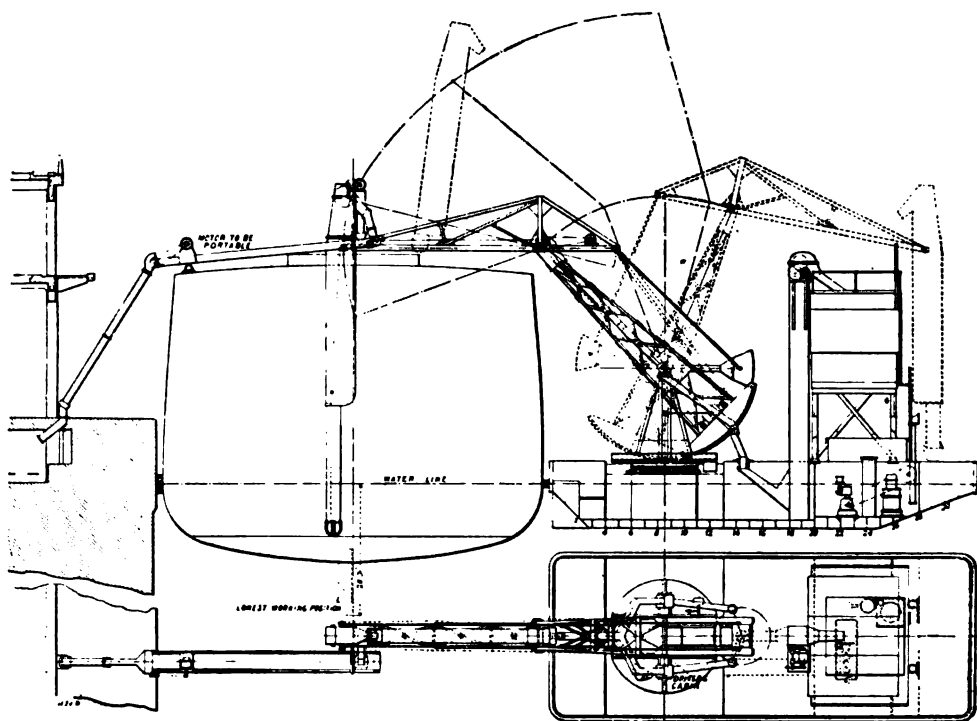


Fig. 735. Mitchell's Floating Barge Elevator.

The elimination of all capsizing movement also enables a very much smaller barge to be used, thereby reducing the capital cost and taking up less room at the ship's side.

The line drawing, Fig. 735,¹ illustrates one of two floating elevators built upon this system to the order of Messrs C. J. King & Sons, Bristol, by Messrs Spencer & Co., of Melksham, Wilts. The maximum capacity of these elevators is 120 tons per hour.

The leg, which is telescopic, has a total length extending to 44 ft. and 27 ft. when closed. The endless chain carrying the buckets is so arranged that when the leg is lowered, as much chain is let off in front as is taken up at the back, so that it remains at constant length and even tension.

¹ The illustrations are reproduced from *The Engineer* of 9th July 1909, while the description is from information kindly furnished by Mr A. H. Mitchell.

Each elevator is driven by a direct coupled electro-motor of 16 B.H.P. at the head of the elevator, thus doing away with all driving chains. It is carried on the end of a cantilever jib of 30 ft. centres, which is in turn carried on the top of a cantilever post of 26 ft. 6 in. centres, the post rotating on trunnions carried on the top of the turntable 16 ft. 6 in. above the deck.



Fig. 736. One of Mitchell's Floating Cantilever Grain Elevators at Avonmouth Dock, in raised position, ready to enter the vessel.

The top of the jib is provided with a conveyor band which carries the grain from the elevator to a shoot running down the post, which in turn discharges into swivelling shoots through the deck into the well of a second, but stationary, elevator. These swivelling shoots are so arranged that they automatically adjust themselves for every movement of the elevator leg. The band is of canvas and rubber, and is provided with diagonal

ribs to facilitate the grain running uphill when the jib is dipping downward more than 20°. The ribs are placed diagonally so that they will run over the return idlers without shock.

The grain is re-elevated by the deck elevator to any required height, and deposited into a hopper from which it is weighed and delivered.

Weighing is accomplished by six "Avery" automatic scales, three on each side, which deliver either into sacks, or shoot loose at will. The elevators are also provided with a means of delivering grain loose and unweighed to barges on either side, and

Fig. 737. One of Mitchell's Floating Cantilever Grain Elevators, in housed position.

also with a portable conveyor for delivery ashore to bands on the quay when necessary.

The range of motion is very extensive, the elevator being able to work from a point 20 ft. 3 in. below the water line, and it can also be lifted clear over the side of a steamer having 40 ft. freeboard (see Fig. 736).

When required for towing, the elevator can be turned right round after the manner shown in dotted lines and stowed over the top of the weigh-house in a position of absolute safety (see also Fig. 737).

The barge upon which the elevator is built is 65 ft. long by 26 ft. 6 in. over all, and has a depth of about 10 ft. 6 in.

The power is generated on board by means of a high speed direct coupled generating set, the engine being built by E. S. Hindley & Sons, Bourton, Dorset, and the electrical machinery by Cromptons, of Chelmsford.

The engine is supplied by suction gas from a plant using anthracite coal. The engine runs at 600 revs. per minute, and transmits continuous current at 110 volts, this voltage having been found most satisfactory for grain work. The current is supplied by means of a concentric connection under the elevator to a driver's cabin attached to the side which contains all the various controllers.

The motor for driving the conveyor is placed at the back end of the jib. Those for raising the jib and the telescopic leg are placed at the bottom of the post whilst the slewing motor is placed upon the turntable. They are each of 4 B.H.P.

The deck elevator is driven by a direct coupled motor placed at the head of the elevator, of 9 B.H.P.

The engines have a maximum output of 50 B.H.P., but the average used when working at maximum capacity does not generally exceed 30 B.H.P., of which about 14 is taken by the main elevator, and the balance by auxiliary machinery and lighting.

The whole of the operations for placing the elevator into the ship and controlling it are carried out by one man from the driver's cabin, the time taken to get into the ship or out being about seven minutes. No use whatever is made of the ship's gear except for the purpose of trimming the grain to the elevator leg. (In some of the earlier types the ship's tackle had to be used to get the elevator leg into the hold).

A similar, but smaller plant, with a capacity of 100 tons per hour, was built by the New Conveyor Co. for the London Grain Elevator Co. Here the buckets are 10½ in. apart and 320 buckets pass per minute.

Two similar elevators, but constructed to run along the quay instead of being placed upon barges, have been constructed for the Co-operative Wholesale Society, Dunston-on-Tyne, as already mentioned.

Floating elevator or marine legs may be preferable to the pneumatic system of unloading cargoes if the grain is stored in a convenient and accessible position, such as if a large hold without obstructions is to be emptied, as the driving power required per ton is only about 1 to 1½ H.P. or approximately half that consumed by a pneumatic plant.

Unfortunately, however, such conditions do not often present themselves, in fact Mr Mowat states that at the Millwall Docks not more than 10 per cent. of the cargo is so stored that it can be handled by the bucket elevator. Cargo steamers, particularly from the Black Sea, contain sometimes many parcels of wheat which have to be kept separate, so that only hand labour or a pneumatic plant can do the work.

A case may be mentioned of a ship which contained forty-seven parcels, which meant different handling for each parcel of grain. Each one had to be taken out carefully by the pneumatic apparatus and cleared before the mats which separate the parcels could be removed to give access to the next parcel. It would be impossible to do this with elevator legs. In some cases the thickness of grain between the separation mats is not more than 2 ft. The only alternative to the pneumatic elevator in such cases is, as already mentioned, the old hand method of bushelling into sacks and making use of the ship's winches and gear to hoist the grain on deck and tip it into barges alongside.

Other difficult cases in which the marine leg is no good are those of cargo steamers

in which grain is carried in empty coal bunkers, or where it is stored at the side of the propeller shaft tunnel which runs through the hold at the after end of the boat; it is obvious that in such cases the grain can only be reached by the pneumatic elevator.

After the marine leg or bucket elevator, when unloading cargoes of grain, has cut down to the bottom of the ship's hold a large quantity of grain heaped at the natural angle of repose remains all round the hold, and every bushel of this will have to be trimmed to the elevator before it can be handled by it. With the pneumatic system the position of the grain is quite immaterial, and wherever it may be, whether under the hatch-coamings or elsewhere, the suction pipes can be led to the grain and remove it from the hold.

CHAPTER XXXIII

FLOATING LOADING DEVICES, INCLUDING SELF-EMPTYING BARGES

WITH the advent of larger vessels the difficulty of loading bunker coal has increased. The larger the ship the more difficult it is to bunker from the quay wall, and for years past the tips for loading have been made portable within narrow limits to accommodate themselves to some extent to the position of the ship, but even with this improvement the adaptability of a floating loading device can never even be approached for portability by a device on shore. On the other hand it can hardly be expected that such floating loading devices can compete as regards capacity with the enormous quantities of cargo coal which may be poured into a vessel by the tips on the quay wall. For bunkering, however, and as an auxiliary to the tip from the waterside, the floating loader is invaluable.

These latter are of three types :

- (A) Those Self-Contained and Carrying the Coal to be Transferred, generally known as Self-Unloading or Self-Trimming Barges ;
- (B) Those which Carry no Cargo of Coal, but Transfer by Mechanical Means the Contents of a Lighter or Barge into Another Vessel ; and
- (C) Colliers Fitted with Temperleys or Similar Devices.

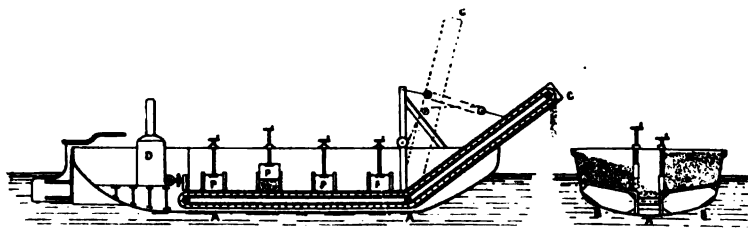


Fig. 738. Paul's Self-Trimming Barge.

A.—SELF-EMPTYING OR SELF-TRIMMING BARGES

Self-trimming barges are used for the purpose of transferring their contents, which may be grain, coal, etc., to other vessels, or to the receiving elevators or conveyors of granaries and coal stores.

Paul's Self-Trimming Barge.¹—One of the oldest self-trimmers, which is, however, not entirely automatic, is the design of the French engineer, M. J. Paul, and will, it is claimed, successfully handle grain, coal, sand, etc.

Fig. 738 shows such a barge, which has a double bottom forming a hollow space *BB* on either side of the channel *A*, in which a travelling trough conveyor is fitted in such a way that its delivery end over the bow is movable like a derrick. Section *AC* of the conveyor can, therefore, be raised or lowered to suit the requirements of the delivery. The angle must not, however, exceed 45° . When not at work the movable part can be housed as shown in dotted lines. The contents of the barge are fed to the conveyor through the

¹ This barge has been minutely described by Professor Buhle.

openings *p*, which are adjustable by means of slides, hand wheels, and screws. In order to enhance the carrying capacity of this barge, the sloping bottom has been made rather flat so that some hand-trimming is necessary. *D* represents the engine and boiler.

Clarke's Self-Trimming Barge.—One of these barges has been in use at Liverpool for upwards of twenty years by the Liverpool Barge and Coaling Co. Fig. 739 shows an elevation in diagrammatical outline, whilst Figs. 740 to 743 show four cross sections giving the different stages of discharge, and they show also how coal of different kinds may be mixed on delivery.

In the space between the double keelsons of the barge a gravity bucket conveyor *a* is provided, which takes the coal to the upper structure and delivers, after passing two

Fig. 739. Clarke's Self-Trimming Barge.

automatic weighing machines, to the delivery shoots *b*, *c*, *d*, and *e*. There are two such barges used at Liverpool, with a capacity of 1,300 tons each, the contents of which can be transferred at the rate of 230 to 250 tons per hour; they require six men each to handle them.

In addition to the barges on the Clarke principle, just described, the Hamburg-American Line has a similar installation at the Hamburg harbour, which shows that although this system is more than twenty years old, it is still considered up to date.

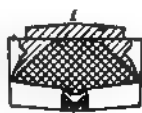


Fig. 740.



Fig. 741.



Fig. 742.

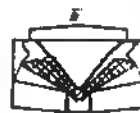


Fig. 743.

The barge is fitted with a crane and grab, so that it can be replenished all the time without having to come alongside for recharging, as there are no suitable tips available at Hamburg for this purpose. The capacity per hour is 250 tons for the gravity bucket conveyor, and for the crane and grab, for replenishing, 150 tons. The height of lift is 48 ft., which is lower than that at Liverpool.

It might be mentioned that it is inadvisable to make such floating loaders too high and top-heavy, and to afford much resistance to the wind in the superimposed structure, as a high wind and an empty barge might prove disastrous; this was probably considered when ordering the self-unloading barge for Hamburg, as somewhere about Christmas 1912 two loaders capsized there.

Self-Trimming Barge in New York Harbour.¹—This is on the same principle

¹ This barge was fully described in the *Journal of the American Society of Naval Engineers*, February 1901.

as the one just described and is successfully employed for the purpose of conveying coal. It has this advantage, that it is really self-trimming, and empties itself completely. It creates but little dust, and the coal is weighed automatically before delivery into the bunkers of the vessel.

Fig. 744 represents a longitudinal section through the barge. *AAA* are the compartments in which the coal is deposited. Each compartment is fitted at the bottom with three slides, which are opened and closed by hydraulic machinery illustrated in Fig. 745. Below the row of slides is a tunnel in which a gravity bucket conveyor is fixed, which is driven by a small engine and boiler at the stern of the vessel.

The contents of the different compartments are deposited in rotation on the conveyor and moved in the direction of the arrow. On reaching the stern, the conveyor ascends, and the buckets are emptied in their highest position into the automatic weighing machines *ww*, from which the coal slides down the shoots *ss* into the bunkers of the steamer to be loaded (see Fig. 746). The shoots *ss* can be raised or lowered by winches. Fig. 747 represents a cross section through this self-trimmer showing the hydraulic machinery for raising the floor of the compartments *A* after they have partially emptied themselves, for the purpose of automatically completing the discharge. Coal can be unloaded from this barge at the rate of 100 tons per hour. Two such self-trimmers are used, one at either side of the vessel.

Self-Trimming Barge of the Pittsburg Coal Co., Cleveland, Ohio, U.S.A.—This barge was built by the C. O. Bartlett & Snow Co., and the illustration, Fig. 748, shows a longitudinal section through the barge, giving a general view of this self-trimmer, and showing the construction, which is as follows:—

The barge is about 165 ft. long by 25 ft. beam, and is large enough to carry 750 tons of coal in addition to her machinery. The main body of the barge is divided into a series of hoppers, each 10 ft. wide, which extend nearly the entire length of the hull. The hoppers *A* are arranged in two rows, one on each side, leaving the tunnel in the centre, which extends from end to end through the barge. Each of the sixteen hoppers communicates with the tunnel by an outlet *B*, which is 3 ft. square. From this the coal can be deposited on a conveyor running through the tunnel. The conveyor consists of two strands of a very heavy chain, to which are connected plates, which form, with the chains, a type of push-plate conveyor. The coal is allowed to pass from one of the hoppers *A* to the conveyor, and is then removed to the terminus, which is raised slightly above the level of the rest of the conveyor. The load is then delivered to the elevator *E*, which is built in a stout sheet-iron frame with ample supports for the guides of the buckets. It is manipulated by two strands of chain, in the centre of which the buckets are hung for the purpose of giving a perfect delivery, as shown in the illustration. The coal is discharged into hopper *H*, which is mounted on a turntable. Immediately beneath the hopper is the well of an inclined elevator, the delivery end of which is so arranged that it can be raised or lowered, and so convey the coal into vessels, which are to be supplied with bunker coal, at any angle from the horizontal up to 45°. To the delivery end of this elevator is attached a telescopic shoot which can be swung round to accommodate itself to the hatches of the boats to be coaled. The whole apparatus, including hopper *H*, is mounted on a turntable, which gives every facility for directing the delivery shoot into any position. The motive power for this inclined elevator is provided by a separate steam engine *C*, which is mounted on the top of the turntable.

It will be seen that the delivery of the coal can be effected on either side of this coaling barge. There is also a second engine *D*, which is placed on the deck of the barge

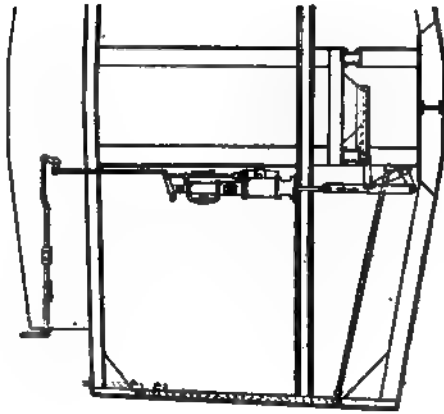


Fig. 745. Hydraulic Machinery for Controlling Slides.

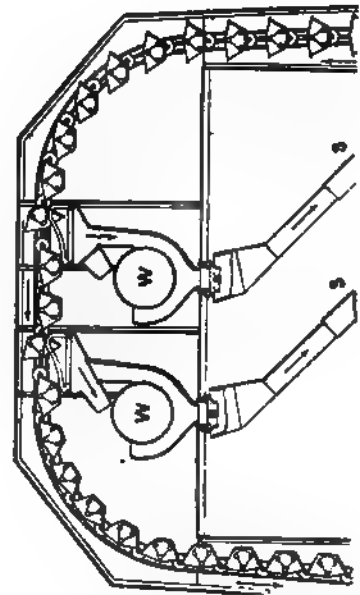


Fig. 746. Discharging Points in Self-Trimming Barge.

Fig. 744. Longitudinal Section through Self-Trimming Barge.

Fig. 747. Cross Section through Self-Trimming Barge.

for operating the conveyor and elevator *E*, as shown. Both engines are fed from the boiler *F*. The unloading capacity is over 200 tons of coal per hour.

Coaling Barges of Werf Conrad, Haarlem, Holland.—This is a well-known type in Continental docks, and one such installation is in use by the Hamburg-American Line at Hamburg.¹ Figs. 749 and 750 show a diagram of the same, and Fig. 751 shows a perspective view. The bucket elevator *a* passes under the coal bunkers *A*, which deliver the contents through openings governed by slides; *b* is an automatic weighing machine. The conveyor passes up the jib *c* and delivers from a receiver down the shoot *d* to the liner. The shoot *d* is manipulated by a 5-ton crane at the end of the jib. The length of the hoppers barge is 157 ft., 36 ft. beam, and 30 ft. deep. The holding capacity is 800 tons, with a draught of 14 ft., and the delivery is at the rate of 200 tons per hour. Seven men only are necessary for all the work. A 100 H.P. compound engine drives the machinery as well as propels the barge.

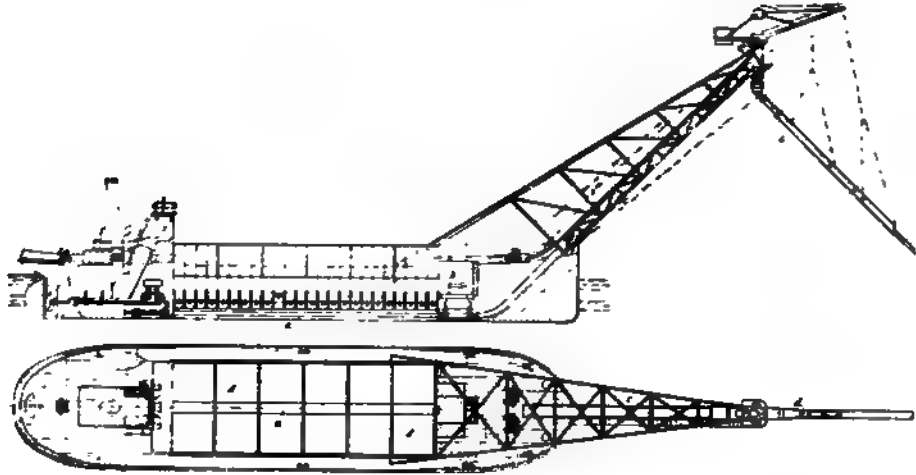
Although the whole construction gives one the impression of stability, it seems at the same time ungainly and difficult to moor in a suitable position for loading.

The Coaling Barges at Doxford Wharf, Sunderland.—There are various other self-unloading appliances, and one of the latest examples is the self-unloading collier, the "Hermann Sauber," built by Messrs William Doxford & Sons, Sunderland, which has a total discharging capacity of 800 tons per hour. The time taken to unload 5,000 to 6,000 tons would be from six to eight hours, and six men only would be required.

¹ At Rotterdam similar ships are in use: the "Pluto" since 1905, "Prosper" since 1907, and "Harpen" since 1909. They all transfer coal at the rate of 100 to 250 tons per hour.

Fig. 749. Longitudinal Section through the Self-Trimming Barge of the Pittsburg Coal Co

Another barge, and more compact than the last, can deliver its coal when berthed alongside the liner, as will be seen from diagrams, Figs. 752 to 754. The capacity is



Figs. 749 and 750. Werf Conrad Coal Loader.

1,900 tons, and the whole of the contents can be transferred to the bunkers of a liner in four hours. The *modus operandi* is as follows: Two steel plate conveyors, *a* and *a*₁, receive the coal from the hoppers *A A* and deliver at *b* by a shoot on to the elevator *c*,

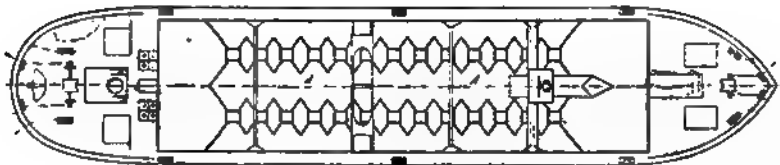
Fig. 751. Perspective View of Werf Conrad Coal Loader.

which again delivers at *e*. The slide *f* regulates the final delivery to shoots *g* and *h*, and thence to the bunkers of the liner.

As modern liners require from 5,000 to 6,000 tons of bunker coal, it would mean that the coaling appliance would have to make at least three journeys to replenish its

contents; or two such barges would have to be at work, one discharging whilst the other replenished; or, thirdly, the bunkering could be done partly by a stationary tip at the dock side, and partly by one of these loaders from the water side. This shows that the systems hitherto described are hardly adequate for bunkering large liners in a minimum of time, but we shall see later that the floating loading devices that carry no cargo coal, but simply transfer the contents of coal barges to ships' bunkers, have adequate capacity for coaling the largest liners. Before describing these, however, we must mention two more self-trimming barges, one of which is specially built to work in conjunction with floating coal loaders, and the other for handling grain.

The Doxford Self-Trimming Barge.—These barges, also built by William Doxford & Sons, of Sunderland, serve the loaders. Fig. 755 shows one of these barges;



Figs. 752 to 754. Coal Loader at the Doxford Wharf, Sunderland.
(The dimensions are in millimetres.)

A is the coal receptacle, B the conveyor, and C and D the final delivery. The general arrangement is not unlike that shown in Figs. 749 and 750, but the delivery shoot is only just high enough to deliver into the elevator of the loader. The capacity of each barge is 650 tons of coal, which is paid out into the loader at the rate of 250 tons per hour. A barge of this kind feeding its loader is shown in section in Fig. 759.

Philip's Self-Trimming Lighter.—This is illustrated in Fig. 756, which gives a longitudinal section of the same, whilst a cross section is shown in Fig. 757. Fig. 758 gives the two ends of the lighter on a larger scale. These boats were designed and equipped by Messrs Spencer & Co., Ltd., of Melksham, for the London Grain Elevator Co.

There is a fleet of twenty-six of these lighters, each of which carries a load of 200 tons of grain from Tilbury to the Port of London, some of the large grain steamers not usually coming up higher than Tilbury. The lighters discharge grain at the rate of

120 tons per hour into a barge elevator, which receives it and discharges it into the granaries of the Port of London Authority.

Between the double keelson of the lighter runs a band conveyor of the ordinary type, the band being 28 in. wide. This band delivers into the elevator situated at the stern of the lighter. Both elevator and conveyor are driven by an electro-motor of $6\frac{1}{2}$ B.H.P. The bottom of the barge is hopper-shaped, as may be seen from the cross section. Although the angle is not sufficient for the whole of the grain to discharge automatically, but little trimming is required to remove any small portions of grain which may remain at the sides after the bulk has been cleared. The openings from the hold to the band are adjustable, and are controlled by means of hand wheels, one at each end of the barge controlling one half of the outlets.

B.—FLOATING LOADING DEVICES

If an expensive loading device has to go backward and forward to replenish its contents, as would have to be the case when loading large liners, it would not be in the least economical, as it would be doing work which a less expensive barge might just as well do, whereas, when continually served with an uninterrupted supply from smaller self-

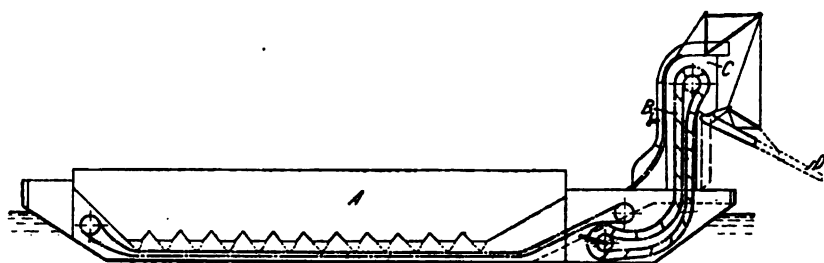


Fig. 755. Doxford Self-Trimming Barge.

trimming barges, an up-to-date loader can handle a surprisingly large quantity in a given time.

Floating Loader built by Smulders, of Schiedam, Rotterdam, Holland.—

When tested for speed and capacity before being taken over at the dock of Rotterdam, this device transferred 1,057 tons of coal per hour from the lighter to the bunkers of a liner, probably the smartest performance of the kind on record.

The elevator stands obliquely athwart the barge, and the incline is alterable to reach right across the ship. This manipulation is performed by hydraulic power, whilst the unloading apparatus is driven by steam power. The inclined elevator is driven by an upright shaft geared on to the upper terminal, and the driving power for the whole plant is furnished by two compound engines of 180 H.P. each. The diagrams, Figs. 759 to 761, are on the same principle, but adapted for different purposes. In both cases the main elevator receives the coal from an automatic self-trimming barge at the point indicated by an arrow. Fig. 759 shows the application of a shorter elevator for serving the bunker inlets at the side of the liner, whilst in Figs. 760 and 761 the elevator is longer and capable of distributing the coal to the side bunkers as well as to those amidship. *a* is the main elevator, *b* and *c* are the supports for the same, as well as for the distributing shoots *d* and *e*, which in their turn supply the coal to the shoots *f* and *g*, which lead to the various bunkering ports.

Typical Floating Elevators at the Hamburg Dock.—One of these is

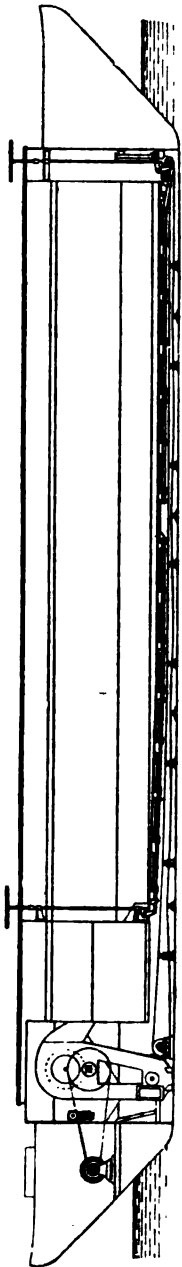


Fig. 756. Longitudinal Section through Philip's Self-Trimmer.

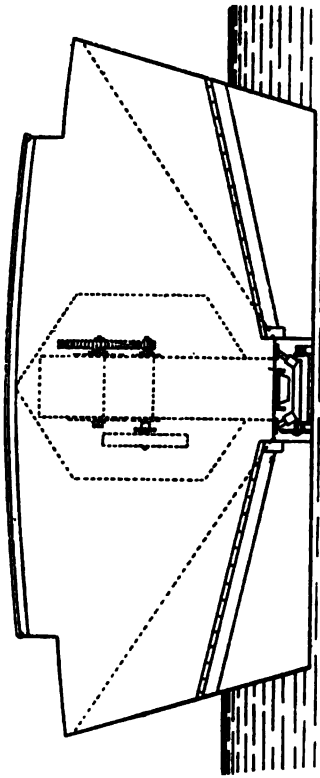


Fig. 757. Cross Section through Philip's Self-Trimmer.

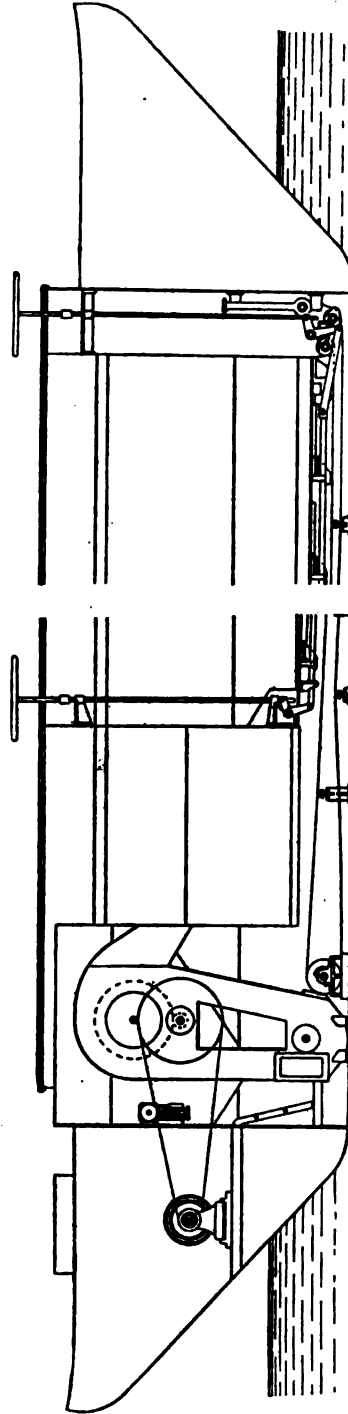


Fig. 758. Giving View of Stern of Philip's Self-Trimmer, also Bow of the Same.

120 tons per hour into a granaries of the Port of L.

Between the double type, the band being 2 the stern of the lighter 6½ B.H.P. The bottom section. Although the automatically, but lit which may remain at hold to the band at each end of the bar.

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Figs. 760 and 761. Another Type of Smulders' Floating Coal Loader.

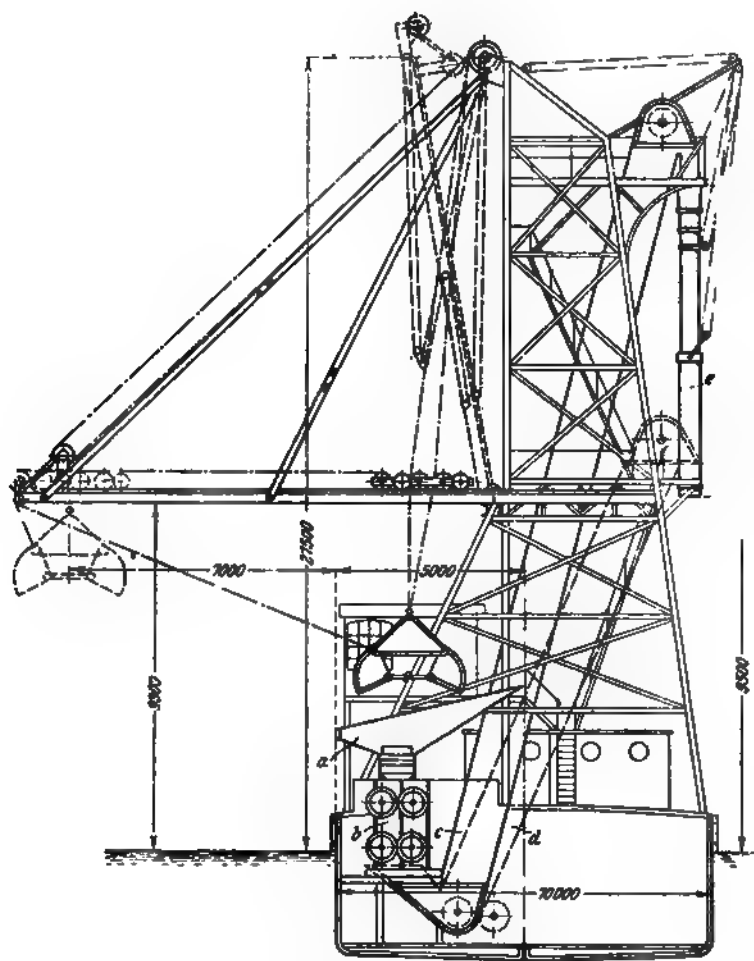
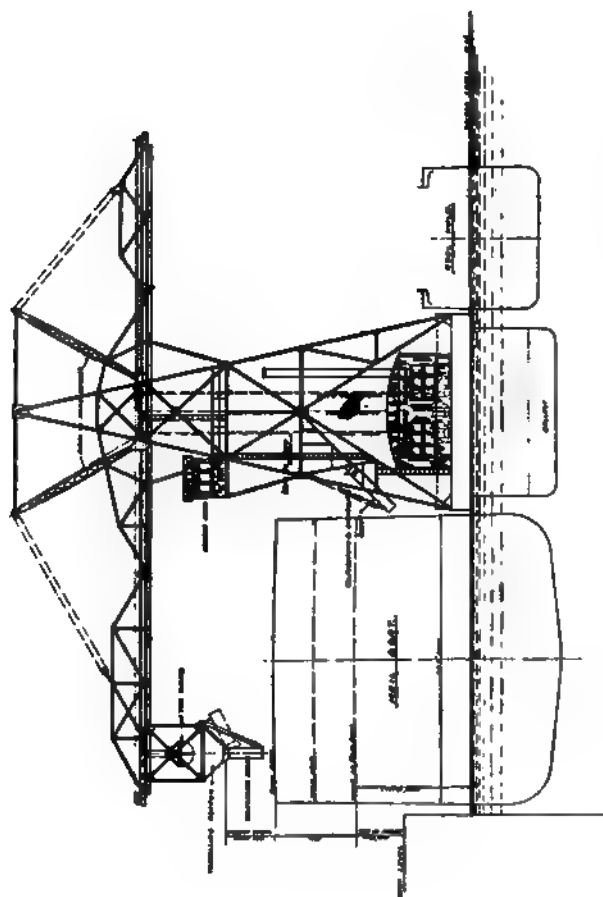


Fig. 762. Floating Coal Loader at the Hamburg Dock.
(The dimensions are in millimetres.)



SECTION, ARRANGEMENT OF PILING AND TRANSPORTER
TABLE BAY HARBOUR
PILING AND TRANSPORTER

Figs. 764 and 765. Floating Transporter at Table Bay Harbour.

hand labour. Before the introduction of this apparatus forty men in the hold and two at the winches would discharge 30 tons of coal per hour per hatch. With the marine transfer one man at the winches can discharge 138 tons per hour without men in the hold.

Unlike other similar devices, the track for the load is here not on a rigid rail but a taut cable (see Figs. 767 and 768). The cables manipulating the grab bucket lead from the drum of the winch over an overhead block, which is supported at a high point above the hatch, the bucket normally plumbing the hatch. The pendant portion of the bucket cable passes through a swinging block, the purpose of which is to deflect the bucket cable,

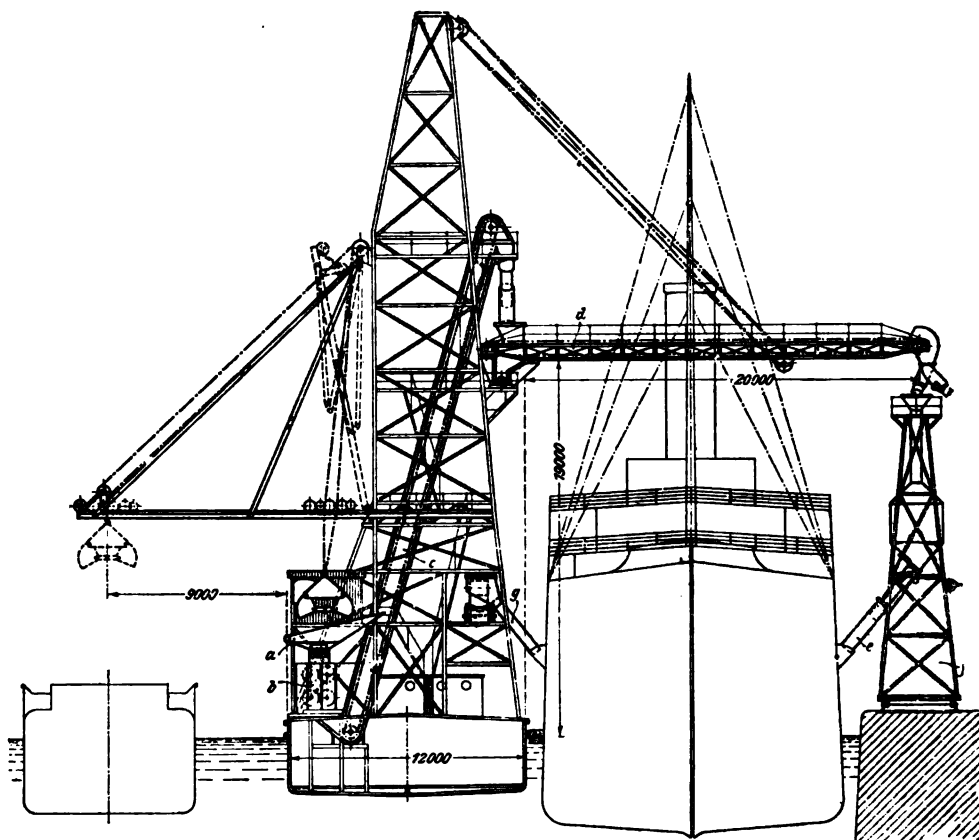


Fig. 766. Floating Coal Loader at Rotterdam.

(The dimensions are in millimetres.)

thus swinging the latter in the manner of a pendulum, from the position where it takes its load to the delivery point. The swinging block is operated by two swinging cables, which are attached thereto and extend in opposite directions round the leading blocks at the end of the outstretched boom, and thence to the drums of the swinging winch. It will thus be seen that there are two separate winches for operating the marine transfer. One winch ("bucket winch") controls the opening and closing of the grab bucket and the vertical motions thereof, while the second winch ("slinging winch") controls the horizontal motions.

The winches have double $9\frac{1}{4}$ -in. by 10-in. cylinders with piston valves. The gears are completely enclosed to exclude foreign substances. Each winch has a piston type

reverse valve. The bucket winch is provided with a metallic brake which is not affected by weather conditions. The control of each winch consists of one pump handle lever, which in mid-position stops the winch; lifted, hoists the load; lowered below mid-position, lowers the load. The reverse valves are of special construction, absolutely controlling the hoisting and lowering of the load at any speed. These winches will handle a $1\frac{5}{8}$ cub. yd. grab weighing 4,000 lb. filled with 1 ton of coal, with 150 lb. steam pressure. The rated capacity of the winches is 100 tons per hour. The actual capacity

Fig. 767. The Marine Transfer as Installed on U.S. Colliers "Neptune," "Jason," and "Orion."

attained under test as mentioned was 138 tons per hour. The average time occupied by each trip of the bucket is twenty seconds.

In the first installations for the U.S. colliers "Vestal," "Prometheus," and "Hector" the winches were of the metallic friction drum type, each being controlled by its own operator. In the latest development of the marine transfer the winches are so designed that they can be controlled by a single operator by two hand and one foot levers; a second foot lever is provided but is only used occasionally for the adjustment of the lines. These ships have very tall masts, thus providing a very high point of support for the overhead block, which is desirable as it greatly reduces the strain in the booms and rigging.

The record of the official test for the two operators with their two winches is 190 tons per hour from a single hatch, made in 1909 with the collier "Hector."

The later installations for two winches (see Fig. 769) with one operator are equipped on the U.S. colliers "Neptune," "Orion," and "Jason." Structural steel A-frames are mounted between the hatches, these structures being connected by a fore and aft girder to which the overhead blocks are attached (see Fig. 767). These girders are also provided with a track-way for the fore and aft transfer of coal for purposes of trimming and bunkering. Fig. 768 shows the U.S.S. "Jason" coaling the U.S.S. "Mars."

Floating Coal-Loading Devices Fitted with Temperley Transporters.—These are largely used. They either transport their own contents to the ship to be bunkered, or they transfer the coal from a barge to the bunkers of the vessel, so that the loading device lies between the barge and the vessel.

Fig. 768. The U.S.S. "Jason" coaling U.S.S. "Mars."

As an example may be cited the one in use at Portsmouth, which holds 12,000 tons of coal for bunkering men-of-war, and carries four towers fitted with twelve transporters, so that the coal can be transferred at the rate of 600 tons per hour. A similar but somewhat smaller installation was built by the Thames Ironworks for Devonport. It has a capacity of 100 tons of coal, which can be transferred to the bunkers of other ships at the rate of 50 to 60 tons per hour. A fleet of five concrete coaling barges on the "Unit" system has been constructed during the war for the British Admiralty. Each barge is 185 ft. long, 35 ft. beam, and 18 ft. deep, and is fitted with four Temperley transporters each having a radius of action of 65 ft. and capable of lifting 300 lb. of coal in each bucket.

Portable Transporters.—These are usually called in the service "Temperleys," and are used in the British Navy for coaling H.M. war vessels, hundreds having been supplied to the British Admiralty, and a considerable number to the French, German, Russian, Italian, Austrian, Portuguese, Japanese, Chilean, Brazilian, and Argentine

Fig. 769. Marine Transfer Winches for One-Man Control, for Operating the Marine Transfer.

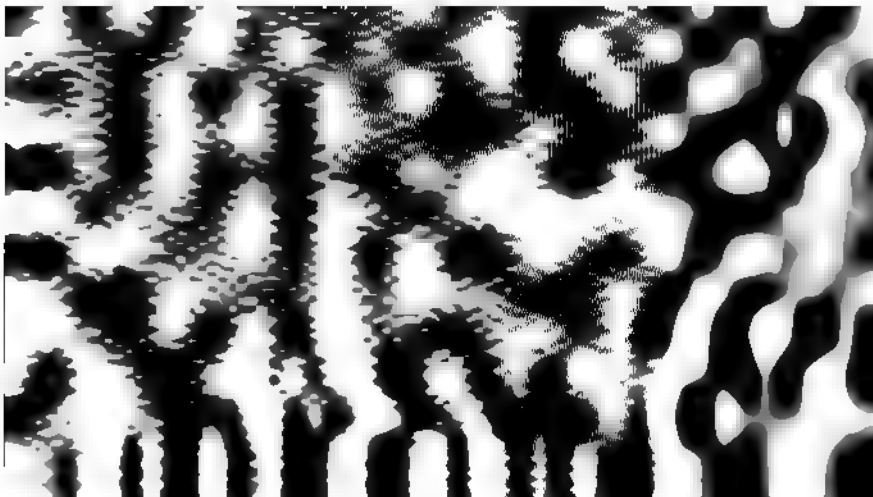


Fig. 770. Small Coaling Vessel fitted with two Temperley Transporters.

Governments. Fig. 770 shows a small coaling craft so fitted. They are also used in increasing numbers on merchant vessels carrying coal, ore, and other cargo in bulk.

The Latest Floating Coaling Device built in this country is that of Spencer & Co., Ltd., of Melksham and London. It consists of two pontoons connected by a steel superstructure which places these pontoons sufficiently far apart for ordinary coal barges to be moored between, and thus unloaded from a bucket elevator which can swing, pendulum fashion, from side to side of the barge whilst the latter is slowly hauled forward by a capstan. This installation was only completed in the autumn of 1921.

General Remarks.—From the description of these coaling devices it will be seen that considerable strides have been made of late in the direction of design and development, and although we are probably better equipped in this country at our principal coal ports than any other country for mechanically disposing of cargo coal, we lack in other ports the facility for transferring bunker coal mechanically into ships, and in this respect some of the Continental ports, particularly that of Hamburg, are in advance. In the Port of London, even, hand bunkering may still be seen, in spite of the continual labour troubles, and where mechanical means are used they are often of the most primitive kind, consisting of a barge with a couple of steam winches which raise the coal in baskets out of the lighters, and then transfer it to the bunkers. By these primitive means, and with nine men filling the baskets in the lighters and emptying them into the bunkers, as well as three men working the winches, etc.—in all twelve men—only 240 tons in ten hours are handled.

In addition to the expense and the time required for hand bunkering, there is a further drawback in the fact that the ship has to be cleaned down after this method of bunkering, which is not necessary after mechanical bunkering.

Notwithstanding the above-mentioned facilities, available at some of the Continental ports, the North German Lloyd at Bremen bunkered almost exclusively by hand before the war.



UNLOADING OF RAILWAY WAGONS

This subject may be divided under two heads, namely :—

- A. UNLOADING BY MEANS OF SPECIALLY CONSTRUCTED SELF-EMPTYING HOPPER WAGONS, GENERALLY WITH BOTTOM DOORS; AND
- B. UNLOADING RAILWAY WAGONS BY MEANS OF TIPS OR HOISTS

CHAPTER XXXIV

UNLOADING BY MEANS OF SPECIALLY CONSTRUCTED SELF-EMPTYING HOPPER WAGONS

SELF-EMPTYING railway trucks occupy a place of the first importance among labour-saving appliances, though British railway companies hardly appear as yet to realise their full importance. The commercial success of many an industry, and especially of that of the production of pig iron, depends to a great extent upon the efficiency and economy of the transport arrangements,¹ and in this self-emptying trucks play a most important part.

The enormous saving to be effected, not only by the adoption of self-emptying railway trucks but also by giving them a considerably increased capacity as compared to the usual 10-ton trucks, is demonstrated by the following figures. For instance, a steel works receiving daily 200 truck-loads of ore and coal would, at a low estimate, pay for the unloading of each truck say only one shilling. This means a yearly expenditure for unloading alone of £3,000, but that sum could be almost entirely saved by the adoption of self-unloaders.

The speed with which such trucks can be discharged saves demurrage and the trucks may be returned for reloading oftener, thus fewer wagons are needed. They are economical in the commercial sense, when the distance to be traversed is not too great, so that say two journeys per day can be made, though it is essential that the quantity to be handled should be sufficient for whole trains to be formed of these self-emptying trucks; special trucks having generally to return empty is not a serious matter for short distances and when whole trains of empties can be returned together.

A factor which militates against the general adoption of large capacity self-emptying trucks for the carriage of coal, either consigned to ports or intended for inland consumption, is the height of the loading screens at some of the pits. The clearance is usually so small, that an increase in height means, in many cases, that wagons cannot be shunted under the screens to be loaded.

In some cases the turntables are not large enough to accommodate longer trucks.

Another difficulty is this, that self-unloading trucks for coal, minerals, etc., are

¹ Those specially interested in this subject will find much useful information in a pamphlet entitled "Private Owners' Wagons," by S. R. Blundstone, published by The Railway Engineer, 15 Farringdon Avenue, E.C.

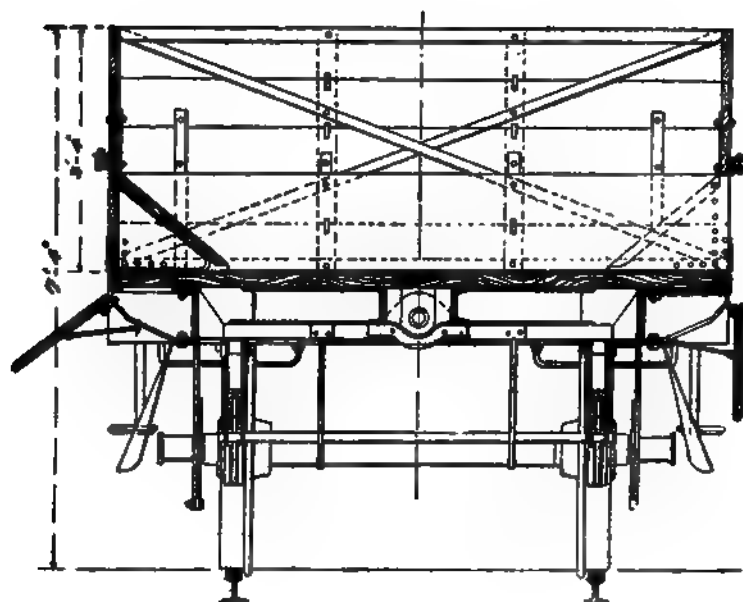
usually conveyed from mines to the manufacturing districts, hence special trucks with hopper bottoms must generally be returned empty, as they are less suitable for the conveyance of ordinary goods. But we shall see later on that there are on the market some types of hopper wagons which are easily convertible into level-floor wagons for the conveyance of ordinary merchandise. It will thus be seen that apart from the private ownership of 10-ton wagons, co-operation between the trader and the railway companies is essential to the successful introduction of self-unloading trucks, and so far traders have been slow to recognise the advantages of this system, and are, to say the least of it, lukewarm in regard to the necessary alterations of terminal plant. Frequently, the sidings are too narrow to admit the larger trucks, for though the wheel base may be the same as in the existing 10-ton wooden wagons, the truck is generally some inches wider. Thus it will be seen that at the coal ports some alterations in the loading appliances will be necessary before the general adoption of such wagons is possible.

The use of self-unloaders can only be beneficial to its fullest extent in conjunction with other mechanical devices and suitable terminal plant for handling the material when unloaded. The most economical method of disposing of the contents of the truck is to raise the railway siding to a sufficient height above the point at which the material is to be unloaded to allow the latter to fall by its own gravity as soon as the self-emptying truck has been opened. In all other cases elevators with suitable feeding devices (which have been fully dealt with elsewhere) will be necessary.

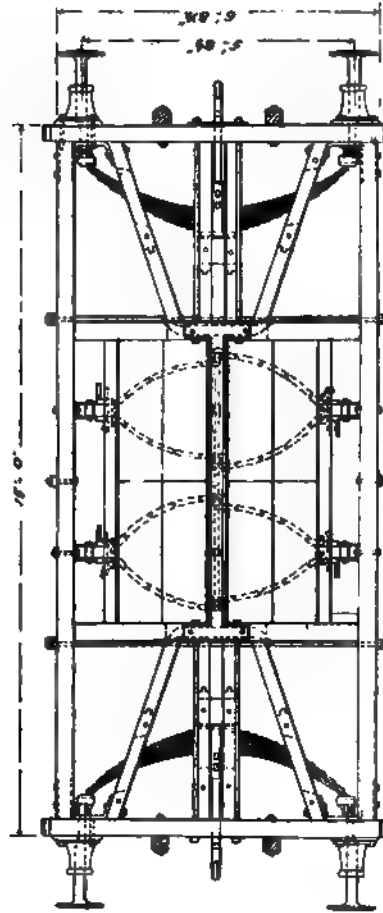
The 15-Ton Hopper-Bottomed Self-Discharging Iron-Ore Wagons of the Alquife Mines and Railway Co., Ltd., which were built by Messrs Hurst, Nelson, & Co., Ltd., are of interest. These wagons are used for conveying iron ore from the company's mines at Alquife, in the South of Spain, to the shipping port of Almeria. The company have constructed a pier at the latter place, and the wagons had to be specially designed to meet both the loading arrangements at the mines and the discharging into the steamers. Owing to the very steep gradients which these wagons have to traverse on the South of Spain Railway Co.'s lines, a certain portion had to be fitted with brakesman's boxes, which are equipped with powerful screw brakes in addition to the vacuum brake. The wagons, 160 in number, are double hopped, and built entirely of steel. A special feature is the arrangement of bottom doors. Close attention has been given to avoiding the waste during transit of any ore, a portion of which is in the form of a fine powder. The principle of the door arrangement consists in the raising at the centre of a pair of V-shaped arms, which are attached to brackets riveted on to the bottom doors. The motion is transmitted by a cross-shaft to a centre lever, which is in turn connected to the door arms by a separate lever which acts on a fulcrum. Suitable arrangements are provided at one side of the wagon to regulate the amount of travel of the doors, and also to secure them in the open and shut positions. The wagons are fitted with side spring buffers, screw couplings, and safety chains, and are quite equal to the class of rolling stock used in this country.

The Lehoen Pressed Steel Co., of Pittsburg, U.S.A., and the Pressed Steel Car Co. were probably among the first to build these trucks largely of pressed steel parts. At the present time close upon a million trucks, the bodies of which have been built principally of pressed steel, are said to be in use in the United States. These trucks are built with capacities of from 30 to 70 cub. yds.; those from 30 to 50 are used for coal, while the largest, up to 70 yds. capacity, carry coke.

It must not be supposed that these steel wagons are more expensive than the old-fashioned wooden ones, or that they compare unfavourably when the capacity per ton is compared with the total cost. The wear and tear on the steel ones is also



[To face page 530.]



Figs. 775 to 777. Self-Unloader of the London and North-Western Railway.

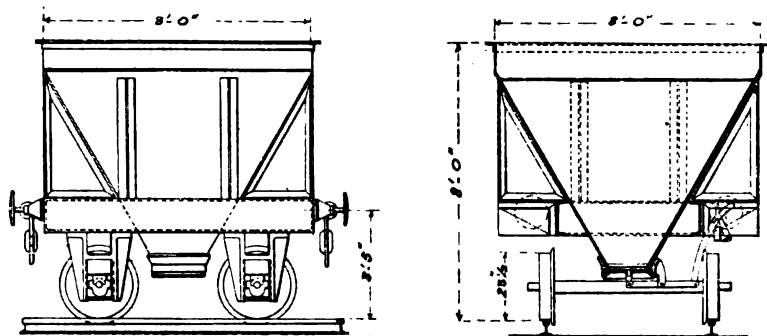
considerably less than in the case of wooden trucks. The weight of a wooden truck of a capacity of 30 tons is 15 tons, whilst that of a pressed steel self-discharging truck of a capacity of 50 tons is $15\frac{1}{2}$ tons. Thus, comparing two trains, one composed of the old-fashioned wooden trucks, and one of the pressed steel unloaders, but both

having a capacity of 1,500 tons, it is evident that in the former case thirty trucks of a total weight of 750 tons would be necessary, whilst in the latter case only fifteen wagons of a total weight of 462 tons would be required, which means that a saving of 288 tons dead weight is thereby effected.

The trucks are so constructed that the hoppers are only raised a few inches above the flaps of the shoots on the unloading staiths. Hence, when the sliding doors are removed, the coal falls on the shoots with but little force, and thus the breakage between the wagon and the shoot leading into the ship's hold is reduced to a minimum.

Self-Emptying Wagons of the North-Eastern Railway.—These are built by Messrs Sheffield & Twinberrow, and are for loads of 35 tons, the tare being 14 tons, or 40 per cent. of the paying load, as against 50 per cent., which is about the average of 10-ton wagons.

Self-Unloaders of the Baden State Railway.—These are built on the Nossian system, in which the body of the car is moved by rack and pinion to one side for unloading purposes. They are, however, slightly hopped on both sides, and therefore empty entirely, whereas the Nossian require the last of the load to be moved by hand.

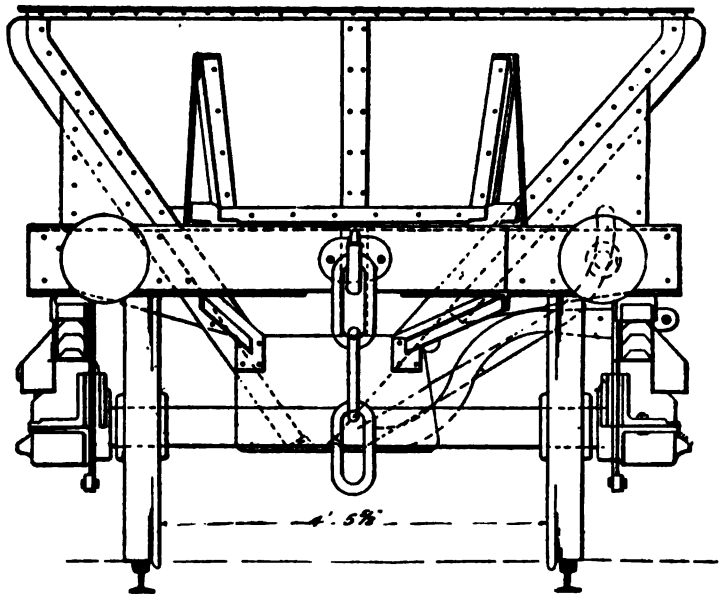
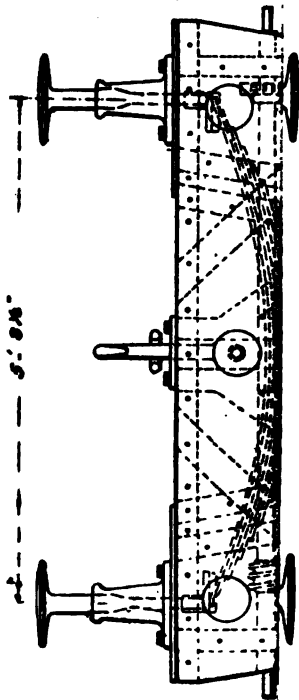
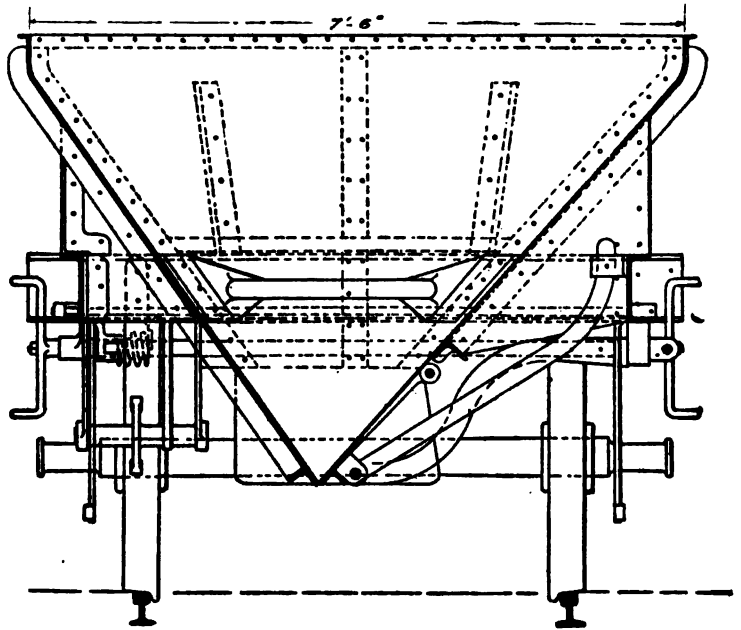
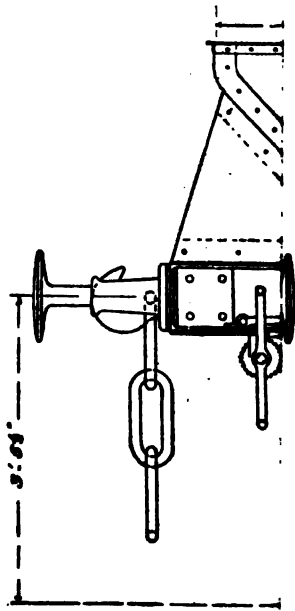


Figs. 782 and 783. Self-Unloader for Liquids.

One of these trucks is illustrated in Figs. 771 to 774. It will be readily understood that the body of the truck need not be moved so far to one side as in the Nossian system. This truck has a capacity of 18 tons. The under frame is generally of iron construction, whilst the upper portion is usually of wood.

Self-Unloader of the London and North-Western Railway.—This self-unloader may be seen in Figs. 775 to 777, which show one of these trucks in plan and two elevations. It is built principally of wood, is hopped, and discharges its load from two large outlets at the bottom of the truck, the discharge being effected by withdrawing a pin which releases the doors. Each outlet is really again divided into two halves, and in the cross section one half of the outlet is shown open. All the other parts of the wagon are clearly seen in the illustration, and require no further description.

Ballast Wagons of the Great-Western Railway.—A wagon of this type is shown in Figs. 778 to 781. These ballast trucks, though self-unloading, have not been built expressly for the conveyance of coal or minerals. They were designed for the purpose of depositing ballast on the permanent way. The operation of laying and spreading is effected as the train moves slowly forward, but there is no reason why wagons of this type should not also be used for the delivery of coal or minerals. The



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illustrations should explain themselves. The whole truck is hoppers and terminates in two large outlets. These wagons were built in connection with the "Rodger's" ballast system.

The train containing these self-emptying trucks has a rear van attached to it with a plough. The nearest hopper to this plough is emptied first, the hopper in advance

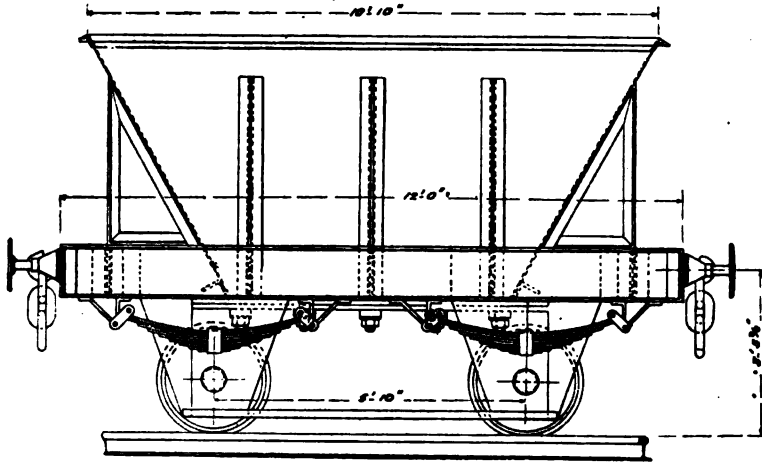


Fig. 784. Type of Self-Unloader.

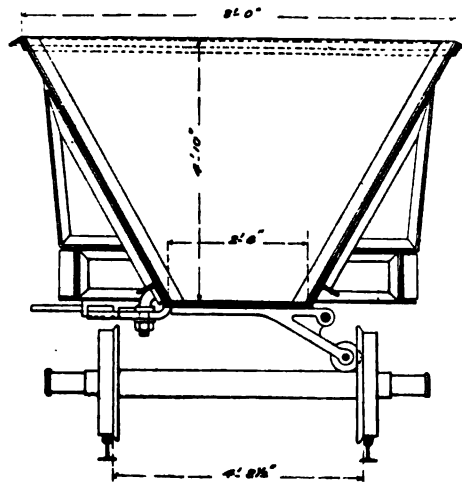


Fig. 785. Cross Section of Fig. 784.

always being opened just before the preceding one is empty. The plough, following the trucks and being a rear vehicle of the train, spreads the ballast evenly, and leaves the road in perfect condition for the traffic. The whole operation of spreading the contents of a train of fifteen trucks, containing about 180 tons of ballast, can be carried out in from eight to ten minutes. In this system only two men (the brakesman and his mate) are required to perform the whole operation, which formerly required thirty to forty men, and occupied some hours.

Self-Unloaders Built by Willich, of Dortmund.—Figs. 782 and 783 represent a special truck which is fully hoppered with one outlet. This is designed for the conveying and discharging of materials such as slurry, slag, lime, etc., and has a capacity of 6 cub. yds.

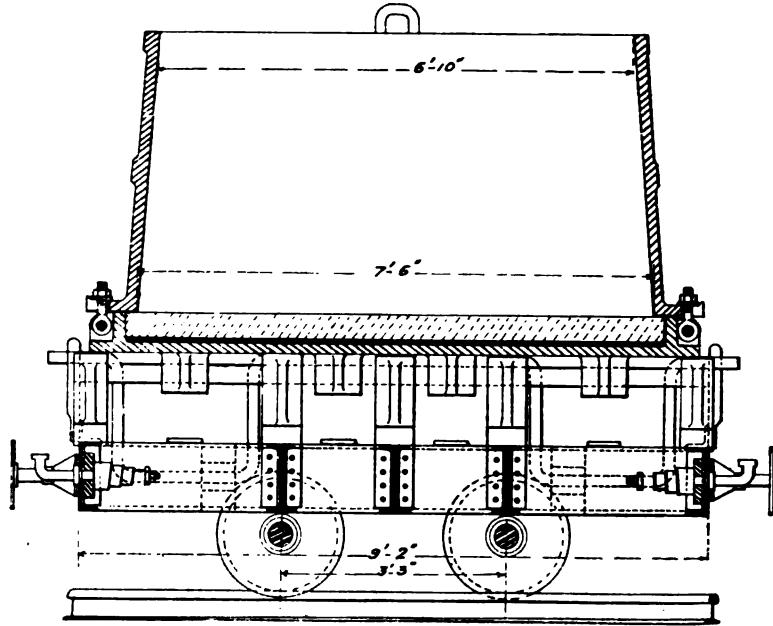


Fig. 786. Self-Unloader for Furnace Slag

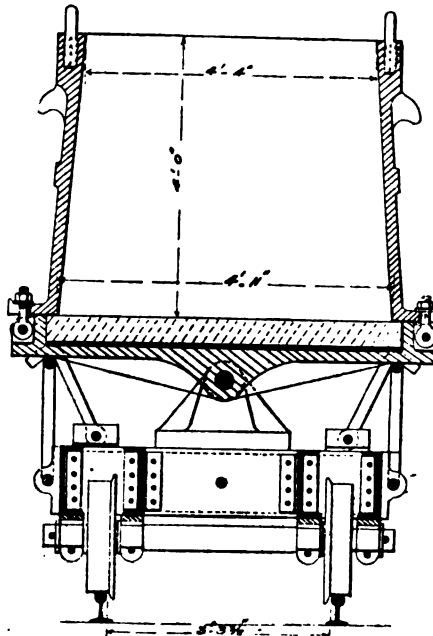
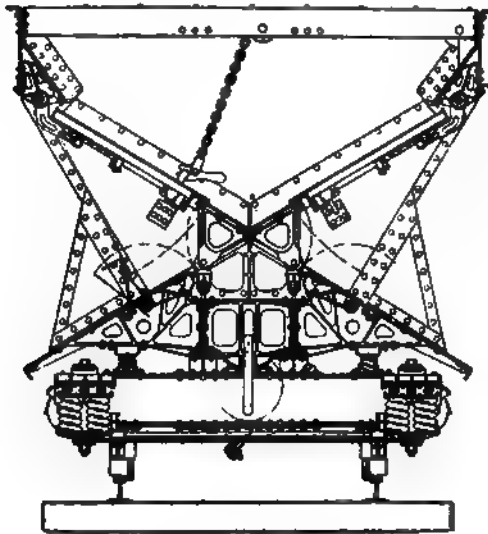


Fig. 787. Cross Section of Fig. 786.

The same firm also make a number of other trucks specially designed for different purposes. Figs. 784 and 785 show one of their special trucks for ore, coal, coke, slag, sand, etc. It is hoppers in both directions and fitted with two large outlets.

Figs. 786 and 787 show a truck specially designed for the conveyance of furnace slag. The illustrations represent the truck in longitudinal and cross section, and explain themselves. The truck can be tipped by pushing the fastenings to one side, and the slag is discharged together with the top portion of the truck. The latter is afterwards picked up by the crane and put back into position. The sides of the car being tapered, the slag readily leaves the truck.

The Goodwin Coal Truck.—In Figs. 788 and 789 are shown an end view and cross section of the Goodwin coal truck, built by the Gloucester Railway Carriage and Wagon Co., Ltd., which has been adopted on several of the American coal carrying lines.



Figs. 788 and 789. End View and Cross Section of Goodwin Coal Truck.

The body of the truck is built upon two plate girder sills 21 in. apart. These girders are 18 in. deep at the middle, and $9\frac{1}{2}$ in. deep at the ends. The space between the sills is left clear for dumping the load between the rails, and from each sill there is an apron or floor inclining downwards. The two ends of the truck are connected by top side plates 18 in. deep, and it is divided in the centre by a transverse bulkhead, so that either of the two compartments can be dumped independently of the other. To the top side plate on each truck, in each compartment, there is hinged a swinging door which, when the truck is loaded, rests on the projection of a movable section in the bottom of the hopper, which is composed of two narrow movable sections hinged to the longitudinal shaft. Each bottom section is held in position by a tripping device, by means of which the said movable section on either side of the truck may be released as it swings downwards, inclining towards the apron, thus releasing the swinging door and permitting the discharge of the load. The apron is hinged along its middle line longitudinally, so that the upper portion can be swung upward. When the upper section of the apron is set in this position and the swinging door released, the latter strikes against

and is held by a spring on the raised portion of the apron, and the contents of the truck are discharged between the sills and inside the rails of the track.

The dumping devices are arranged to be operated either by hand or by compressed air, hand dumping being accomplished by means of a wheel at the end. When equipped for pneumatic dumping, an air cylinder is attached to the outside end of the truck in proximity to the hand wheel.

A few methods of discharging are shown in Figs. 790, 791, and 792. The truck is 35 ft. 11 in. long over the end sills, 8 ft. 10 in. wide over all, while the extreme height from top of rail is 8 ft. 6 in. The carrying capacity is 40 to 60 tons of ore, and with the load heaped it amounts to about 40 cub. yds.

Self-Discharging Ballast Wagon of the Leeds Forge Co., Ltd.—

This wagon is arranged to discharge its contents in whatever direction is required, either at one side or the other, or at the centre, or in different directions together, and so that the rate of discharge in any one direction can be regulated and stopped, when required, independently of that in the other directions. An alteration from any one direction to any other may be made during the progress of discharge, or the discharge may be entirely stopped at any or all points before the wagon is empty.

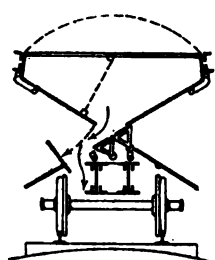


Fig. 790.

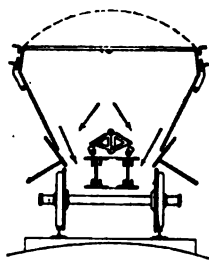


Fig. 791.

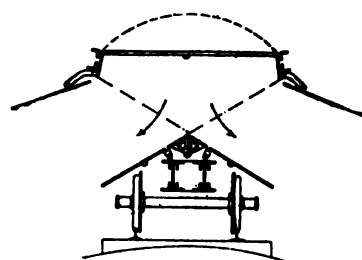


Fig. 792.

Methods of Discharging with the Goodwin Self-Emptying Truck.

An illustration of one of these wagons as supplied to South American and to Indian broad-gauge railways is given in Fig. 793. Similar wagons have been supplied to the South-Eastern and Chatham Railway, and to the Indian metre-gauge railways.

The opening and closing of the doors, and regulation of the amount of material discharged, are entirely under the control of the operator standing on the platform of the wagon, so that it can be used for discharging ballast on the line. On the South-Eastern and Chatham Railway a full train load of 133 cub. yds. of ballast was discharged in twenty minutes with only three men in attendance, while an ordinary ballast train composed of fourteen 7-ton trucks, and holding only 98 cub. yds. of stone, took one hour ten minutes, with 28 men in attendance, to discharge its load on the same piece of road.

It will be seen from the illustrations that the operating gear is strong and extremely simple, and is not liable to get out of order. The control can be arranged either from an end platform or from the ground.

The diagram also shows how this type of wagon can be constructed with provision for the addition of a flat door to enable it to be used as an ordinary flat-bottomed wagon, and how also, if desired, it may be provided with drop sides and ends to facilitate the loading and unloading of rails, timber, etc.

Fig. 794 shows another type of hoppered wagon built, among others, for the Madras

Railway, the principal dimensions being height, 10 ft. 10 in.; gauge, 3 ft. 3½ in.; load, 18 tons 10 cwt.; capacity, 450 cub. ft.; and tare, 8 tons 11 cwt.

Self-Discharging Drop Bottom Wagon of the Metropolitan Carriage, Wagon, and Finance Co., Ltd.—The floor is formed of sixteen doors, which are hinged to two central girders running the whole length of the wagon, these girders forming one box girder which carries the load, and takes the buffer and drawbar strains. The doors are operated from each corner, and when closed make a level floor to the wagon. A small hand wheel releases the safety catches, and the doors are raised and lowered by a lever handle working, through spur gearing, a worm and screw to each pair of doors, the latter being fitted with ball-bearing footsteps. Each handle operates four doors, and all the gearing is cased in to ensure efficiency. A hinged door is placed in the centre of each side of the wagon to make it applicable for loading ordinary goods. The under frames and floor doors are built up of mild steel channels, plates, and angles;

Fig. 794. Side-Discharge Ballast Wagon.

and automatic couplers with tandem buffing and draw-gear are fitted. Westinghouse quick-acting brakes are likewise provided, working in conjunction with a hand brake. The bogies are of the standard American type, with girder bolster and nests of spiral steel springs. The wheels have steel disc centres with steel tyres and axles.

Capacity and Leading Dimensions

Capacity.	Dimensions.
Load (in pounds) - - - -	100,000 lb.
Capacity (in cubic feet) - - -	1,790 cub. ft.
Length over headstocks - - -	41 ft. 9 in.
Length inside - - - - -	40 " 0 "
Width inside - - - - -	9 " 3 "
Height inside - - - - -	4 " 10½ "
Centres of bogies - - - - -	30 " 0 "
Journals - - - - -	10 in. × 5½ "
Gauge - - - - -	4 ft. 8½ "
Tare - - - - -	21 tons.

60-Ton Self-Propelled Hopper Wagon.—Self-unloading trucks with the large capacity of 60 tons have been installed by the Virginian Railway Co. in connection with their coal loading and shipping scheme at Sewell Point, Norfolk, Virginia. These self-unloaders deserve special notice, as they are motor-driven or self-propelling; one of them is shown in Fig. 795. The motive power is produced by two 90 H.P. electro-motors, one at each end of the wagon. The unloading doors are manipulated by compressed air.

Self-Unloaders of the Pennsylvanian Railway.—This company has recently

Fig. 795. 60-Ton Self-Propelled Hopper Wagon.

installed one thousand coal and coke wagons. One of these is illustrated in Fig. 796. The wagons unload through bottom outlets on each side, affording eight openings for material to pass, presenting a total aperture of 80 sq. ft. The length of the body of the wagon is 40 ft., the carrying load 45 tons, and the capacity is 2,400 cub. ft.

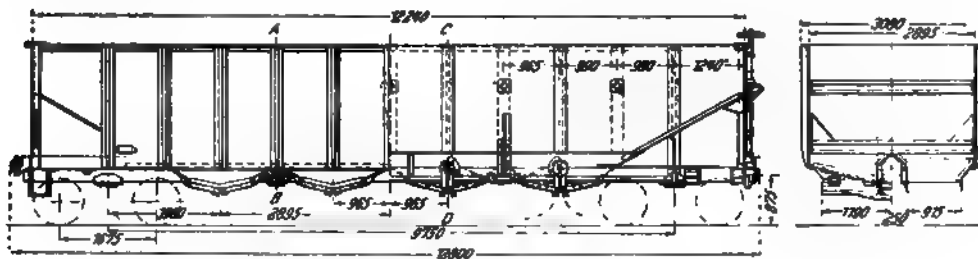


Fig. 796. Self-Unloader of the Pennsylvanian Railway.
(The dimensions are in millimetres.)

Bulk Transit of Grain by Means of Railway Trucks.—The bulk transit of grain has been brought to great perfection in the United States, and there is no doubt that in this country some progress has been made amongst the larger inland flour millers. It may freely be admitted, however, that to many mills in this country the bulk transit of grain would be of little or no use, but on the other hand there seems to be a large field for its adoption in granaries and merchant mills of fair capacity, of which the inland position makes the mechanical handling of material (at least at the terminals) a matter of vital importance.

The mills that may fairly dispense with the bulk handling of grain are at the two

ends of the scale, namely, the small country mills, to which grain is brought in farmers' carts from the immediate neighbourhood, and the large port mills, which receive foreign wheat either directly from ocean-going steamers at the quay side or from barges that have been loaded in bulk or with sacked goods from the ship. One of the strongest arguments in favour of the bulk transit of grain is the saving in terminal charges which the general adoption of such a system would be likely to bring about. Under present conditions, no doubt, railway companies may fairly argue that it would be unreasonable to ask them to reduce terminal charges whilst only a fraction of the larger merchant millers of the kingdom have adopted the system. The possible economies of the bulk system of grain handling are well illustrated by a comparison of the freight rates between Chicago and New York, and between Liverpool and Manchester.

Taking the rates current at the close of year 1902, the rate per ton between Chicago and New York amounted to about 15s. 6d. for about 800 miles, while the rate per ton between Liverpool and Manchester on a haul of 31 miles amounted to 6s. 11d. Thus it will be seen that the rate on the long haul amounted to about one-fifth of a penny per ton per mile as against 2½d. per ton per mile on the short haul. There is no question but that railway freights for grain are excessive in this country, generally speaking, and although in this as in other problems many factors enter into the composition of the rate, yet it is clear that the handling of grain in sacks tends to keep up the high rates. One of the lowest rates for grain current in England is probably that which is in force between Hull and Newcastle, where, before the war, 7s. 6d. per ton was charged on a haul of 110 miles, equivalent to about eight-tenths of a penny as against one-fifth of a penny for 800 miles' haul in the United States.

It is easy to understand why the bulk handling of grain is likely to effect great economies in transport. The labour bill is considerably reduced, and as covered trucks are used, no waterproof sheets are to be provided, while the item for labour in connection with these sheets is also saved. Moreover, considerably less shunting is required with the bulk system of transit for this reason, that the space occupied by a 7-ton truck loaded with sacks will not be exceeded by a 20-ton bulk car.

When grain is handled in bulk, much greater loads can be carried in a single train. At a moderate calculation, the general adoption of the bulk system, with self-emptying railway trucks, in this country, would enable the railway companies to reduce their terminal charges by at least 33 per cent. According to *Milling*, a journal to which thanks are due for many facts in connection with the important question, "No miller can realise the full economy to be obtained from the bulk handling of grain unless he has his own siding."

To show how wide-reaching are the economies possible with a well-organised system of bulk transit, it may be noted that the difference at most of our ports between the overside and the quay rate amounts to about 7d. per ton. Under the present system of sack handling the miller is often compelled to buy *ex* quay; whereas with a reasonable track-to-car rate, millers whose grain was handled in bulk would be able to buy *ex* ship. Moreover, the petty pilfering which goes on more or less where sacks of grain are handled would be rendered well-nigh impossible by the use of bulk trucks, which could be sealed or locked, thus reducing the liability of shortage to the lowest minimum.

Perhaps one of the best examples of bulk grain handling now to be seen in England is afforded by the Industrial Co-operative Society's Mills at Leeds. The bulk of the wheat used in these mills is bought at Hull, and is conveyed in the Society's boats to a transit silo on the banks of the river Aire. This installation may be considered a receiving station for the mill's raw material. Two bulk cars are continually passing

between the mill and these transit silos, taking wheat away as fast as the boats are unloaded. These cars were built by the Society's own workmen, and have a carrying capacity of 5 tons each. The method of loading and unloading is most simple. The roadway passes right under the silo bins, and as the bulk trucks are drawn in at one end of the building they can be rapidly loaded and passed out at the other end. Not more than three minutes are required for this operation. By a simple lever arrangement a slide is opened in the hopper of the bin from which it is required to draw wheat, and in two minutes 5 tons of wheat have entered the car. Then the slide is promptly closed and the car passes on its journey to the mill. On arrival at the mill the cars can be unloaded with a minimum of labour by a simple tipping device, receiving hopper and elevator. Not more than two and a half minutes are, it is said, required for unloading each truck.

There is no doubt that before the bulk handling of grain can come into general use in this country it will be necessary to devise a thoroughly practical form of truck. So far as the author is aware, but one railway company, the Lancashire and Yorkshire, have provided trucks of their own design for this particular traffic. These trucks have a length over head stocks of 35 ft., and a width of 8 ft. The inside height at the sides is 6 ft. 1 in., and at the centre 7 ft. 1 in., and the capacity is 1,563 cub. ft. The wheel base of the bogies is 5 ft. 6 in., with 25 ft. between bogie centres. They have a carrying capacity of about 30 tons of wheat, but have been criticised by millers on account of the large amount of trimming that is required before they can be entirely emptied. It is, by the way, alleged that this particular design was a sort of compromise between the purely bulk grain truck and a truck that might be used for other kinds of merchandise, such as cotton, which are carried on this particular line. What is required is a truck of large capacity that can be securely fastened, to prevent tampering with the loose grain, and will automatically discharge at its destination without the necessity of hand trimming. Spencer & Co., Ltd., of Melksham, have built a truck for carrying loose grain which is provided with a hoppers bottom, but if it be desired to use this truck for sacked goods, a flat floor can be laid over the hoppers. A very good bulk truck is built by the Metropolitan Carriage, Wagon, and Finance Co., Ltd. In adapting the bulk system to the conditions current in this country, it should always be borne in mind that the immense loads of grain which are carried over the main trunk lines of the United States would be out of place in Great Britain, where flour mills are on a much more modest scale than the giant merchant mills which are to be met with at certain points in the winter-wheat, and especially in the spring-wheat belt of the United States. Again, but few of the dock companies of the United Kingdom are prepared to handle bulk grain, that is to say, to load bulk cars. The Manchester Ship Canal Co. has, however, provided automatic scales and loading shoots, by means of which loose grain can be weighed and shot into trucks adapted for this traffic. The Manchester grain silo and elevator are well provided with railway sidings, being connected with every railway system running into Manchester, so that here are to be found all the elements for a rapid extension of this system of grain handling on the railways of Lancashire, Yorkshire, and of the Midlands. All that would seem to be required are more convenient bulk trucks, which the railway companies should provide, and tipping pits or hoppers to receive the grain in bulk from the flat-bottomed trucks which are tipped to empty, or from hopper-bottomed self-emptying trucks, which should be provided by the owners of sidings where grain is received in bulk trucks for the service of either flour mills or granaries.

Hopper-bottomed trucks are to be preferred on account of their quicker discharge.

Unfortunately such trucks would not be of much good for other purposes. The author would suggest covering the wide end of the hopper with an iron grating composed of flat iron bars with a mesh of 2 to 2½ in. This grating could be used as a floor for the reception of sacks. The mesh would not be too open to walk upon, and the grating would not be in the way when filling or emptying loose grain.

The Lidgerwood Rapid Unloader.—This can hardly be called a self-emptying railway truck, it really being a self-unloading train of trucks, whose vehicles are discharged in quick succession by mechanical means.

This appliance is used on a complete train of flat-bottomed trucks with a guard on one side and open ends, the spaces between being bridged over by steel aprons hinged to their ends. By means of a cable and a plough the whole of the trucks are mechanically emptied. To begin with, the whole train is loaded by a steam navvy, the train of trucks forming one continuous trough without any divisions.

When a train of this character arrives at the dumping position with its load, the locomotive is disconnected and leaves the train in charge of the dumping engine. A typical method of unloading is as follows: Between the dump engine and the train is a special car on which a Lidgerwood winding drum and engine are arranged. The whole train is moved up to the point of entrance upon the actual dumping position, and here a chain is temporarily stretched across the track just back of the car containing the winding drum, the ends of the chain being secured to two suitable poles, one on either side of the track. The free end of the steel cable on the winding drum is now attached to the transverse chain. The dump engine now goes forward carrying the train with it, the winding apparatus permitting the cable to unwind at the forward movement, which continues until the rear of the train has arrived at the two poles. The cable now extends all along the pile of spoil, and the end which has been temporarily secured to the transverse chain is now unfastened and attached to the great plough on a separate car, this plough having a single face extending obliquely across the floor of the train. The train itself is now in the desired position on the dumping spot, and the actual unloading is accomplished by operating the winding engine and drawing in the cable. The plough is drawn along the whole train, its great weight and form being sufficient to maintain it in proper position as the ploughing goes on. The spoil is pushed off the train on the open side, and falls in a long ridge close to the track.

The trucks used are 39 ft. 8 in. long by 8 ft. 9 in. wide inside, the one side being 3 ft. high. The doors are hinged from the top to swing in an outward direction. Twelve such trucks were loaded in thirty minutes on one of the American lines, and over 4,000 cub. yds. of material have been handled by the steam shovel and train per day.

The cost of filling such trucks on the Kansas City Southern Railway, U.S.A., for the months of March, April, May, June, and July 1900, is stated to have amounted to 2.89 cents per cubic yard, or about 1½d.

The Lidgerwood system was employed to a very large extent in the construction of the Panama Canal, chiefly on that part which was named the Tabernilla Dump.

At one dumping point, Tabernilla, a total of over 34 miles of track was shifted during a month, and as this implies the relaying of 1½ miles of track per day, we may get an idea of the rapidity with which the dump piles were growing. On a typical day fifty trains, each containing sixteen wooden cars having a capacity of 20 cub. yds. each, would be unloaded by the ploughing method at Tabernilla alone. This work was performed by four unloaders, so that a single unloader handled, on an average, 4,000 cub. yds. per day, or 500 cub. yds. per hour. At Tabernilla there were, in

Fig. 797. The 25-Ton Pull Lidgerwood Unloader Engines.

addition to the four unloaders, two spreaders for dispersing the soil, two trackshifters, one pusher engine, and one switch engine.

Fig. 797 gives a full view of the unloading mechanism, which is built for 25 tons' pull. The illustration shows the way in which the steam supply from the locomotive boiler is taken to the engine of the winch, the pipe being fitted with flexible joints to allow for any movement or vibration.

In Fig. 798 the loaded plough may be seen at work unloading a train. The winding gear near the locomotive engine can also be seen in the distance.

This device is the design of the Lidgerwood Manufacturing Co., of New York.

The Western Dump Cars of the Western Wheeled Scraper Co., of Aurora, Illinois.—The Western dump cars are used for contractors' work, similar to the Lidgerwood, and have also been largely used in the construction of the Panama Canal ;

Fig. 798. Rear View—Loaded Train with Plough.

in the building of railways on the Mesabe Rangé, in stripping the over-burden from the ore beds ; in the Florida phosphate fields ; and on practically every great constructional work that has been accomplished in the United States of America. Figs. 799 and 800 show two views, back and front, of one of the trucks in the dumping position. The bed or platform of the car is pivoted longitudinally in the centre, and will dump on either side. When dumping, the hinges bolted to the centre sill under the platform move on the pedestal castings, which are bolted to the draft beams. The connection consists of a flat bar which drops loosely into the socket of the pedestal in a perpendicular position, the upper end of the bar being held between the lugs of the platform hinge by a pin. The weight of the car does not rest upon the horizontal pin, which passes through the hinge so that there is no liability to bend the pin. The arms operating the doors act automatically. When the platform of the car is tipped, the toggle strikes a plate fastened to the car frame and holds the door from dropping with the platform.

Either side opens as the car is dumped and closes as the platform is returned to its original position, both automatically and instantly. The door arms are pivoted, both where attached to the door and to the platform, in such a manner that, as the platform is tilted, the doors are thrust outward and upward from the load, so that no part of the load as it moves is thrown against the door, and any danger of derailing the car by the impact is removed. When the platform is dumped the open side door is brought to a position nearly parallel with the bottom of it. On account of the free vent for discharge and the acute dumping angle, anything that can be loaded into the cars will clear the side board in dumping, so that heavy rocks and boulders of frozen earth in large masses can be easily handled. The beds or platforms are held in position by chains on each side connecting with the truck, and provided with spike and ring fastening, which can be released by the hand or foot while the car is in motion. These safety chains practically avoid all possibility of the car dumping accidentally, which might cause serious mishaps. The arms and the toggle-jointed

Fig. 799. Western Dump Car (Back View).

levers which operate the side door are all connected to the platform and not to the truck, so that when the side chains are unlatched, the platform and truck are entirely separable.

During dumping the platform is not held rigidly to the trucks, but is permitted to rise slightly from the pedestal at the moment of the shock, so that there is no tendency to lift the truck from the rails. In the event of derailment and rolling down an embankment the platform and truck automatically separate, causing less damage to the car and making its replacement on the track much easier. The bearing on which the platform turns in dumping is of such construction and adjustment as to make the dumping and returning of the platform to position very easy. The dumping angle of the car is from 45° to 75°.

At the dumping ground of Gorgona, during the construction of the Panama Canal, eight trains consisting of twenty-five cars each were used, and as the cars had a capacity of 17 cub. yds., a daily total of 3,400 cub. yds. were brought in this one type of car to this one dump. At Mamei, 10 miles away, both large and small Western cars were dumping 1,500 or 1,600 cub. yds. per day, and so also at other points. Three trains of large dumping cars were run daily from Bas Obispo to the side of the great dam carrying

1,200 or 1,300 cub. yds. of rock to be dumped on to the south toe of the structure. This haul was one of 24 miles.

The "Hunt" Automatic Railway.—A practical method of carrying heavy material, such as coal and ore, from wharfside or railway to the stock heaps or storage bins, is the "Hunt Automatic Railway," operated entirely by gravity, no motive power or manual labour being required. The salient point of this system consists in the sufficiency of energy which is acquired by the loaded truck descending an inclined track. This energy is utilised, after the discharge of the load, for returning the empty truck to the place whence it started.

The railway is loaded at the upper terminal with ore or coal from a small hopper into which the unloading grab discharges. One man is sufficient to operate the installation; he loads the truck by opening a slide in the small hopper, but its further progress being entirely automatic, he does not accompany it. It runs down the track, discharges its load at any predetermined point, and then returns empty to the receiving terminal. The time taken in making a trip of 300 ft., dumping the load, and returning to

Fig. 800. Western Dump Car (Front View).

the starting point, is about fifty seconds. As the loaded truck descends it gains in speed, and as it approaches the end of its trip it raises a weight by means of a wire cable and tripper with which it comes in contact. At this point the load is automatically discharged, when the inertia stored in the aforesaid weight is given up again to the truck to afford it a sufficient start, so that its own momentum will carry it back again to the starting point. It is important that the raising of the weight should form a gradual movement, in order to minimise to the utmost any stress on the various parts of the mechanism.

Fig. 801 shows the details of such a plant at work at the Avonbank Electricity Works, Bristol, and erected by Babcock & Wilcox, Ltd. A general drawing of this installation will be found facing page 691.

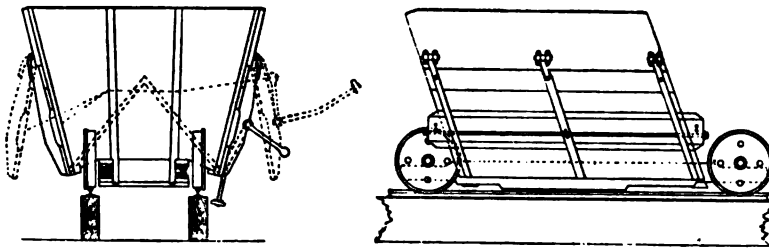
The ordinary method of discharging these trucks is by opening the sides by means of a tripping block placed on the track, to let the load out on both sides.¹ The floor of the truck is A-shaped in order to run the material clean out (see Figs. 802 and 803).

The sides are hinged, but the lower ends are fastened, not to the truck, but to each other; thus if one is unfastened, both are open. The load is always evenly discharged,

¹ For similar self-unloaders see Chapter XXIII. on Rope Haulage, page 285.

and there is practically no risk of the truck overturning, though the gauge is a very narrow one, being only 21 in. from outside to outside of rail heads. These cars are built of wood, and lined with sheet steel, and are provided with self-lubricating bearings, rubber springs, and steel axles. The bearings are of a peculiar construction, and are so arranged that the car will run round a curve of 30 ft. radius with practically the same ease as on a straight line. The steel wire rope which raises the weight is detached from the truck, except during the time that the car is raising the weight, and receiving the impulse to return. Curved tracks are admissible, but should be as near the feeding terminal as possible; they require special rails to suit the flexible running gear used on these cars. All material received over the railway can be weighed by placing platform scales on the track at the loading end. The attendant who loads the trucks can also, at the same time, weigh the loads, and enter the weight in the tally book as the trucks are running down the track. On account of the width of the truck, and owing to the distance to which the side doors open out, the scale beam must be further away from the end of the platform than usual. If desired, automatically registering weighing machines may be used, for description of which see Chapter XLIII.

The "Hunt" automatic railways are suitable for distances not exceeding 600 ft. The trucks are built in two sizes, the smaller carrying 1 ton and the larger 2 tons, and



Figs. 802 and 803. Truck used for Hunt's Automatic Railway.

they have been chiefly used for handling coal, but are equally suitable for other heavy material, such as ore, phosphates, clay, etc. The construction of the truck, including the shape of the base, is varied according to the nature of the material to be conveyed.

Amongst "Hunt" automatic installations may be mentioned one at the Storey Coal Yard, Brooklyn, New York, where two trucks on separate tracks distribute all the coal hoisted by a 2-ton grab to a pocket which holds 7,000 tons.

The Calumet and Hecla Mining Co., Lake Linden, Michigan, U.S.A., use five 2-ton cars which run on twenty-seven automatic tracks. The "Hunt" system may also be seen in operation in Dublin, where it is used by the United Tramways Co. At Ludwigshafen, on the Rhine, it has been installed by the Westfaelisches Kohlen Syndicat, also at the gasworks of Zürich, which latter plant is illustrated and described on pages 481 to 484.

The principle of this automatic truck is very simple, but the conditions under which it is used vary widely. For instance, it may be made to serve the largest coal yard by means of a number of tracks converging on one or more points. The track or tracks may be placed at any height, and, if desired, the truck may be made to dump from an elevated track at any given point, to build a pile of coal in the storeyard. The track on which the car runs may be carried by a movable bridge (controlled from the hoisting tower) which will itself serve a wide area. The Lehigh Coal and Iron Co.'s

Wharf at West Superior, Wisconsin, U.S.A., is 2,000 ft. long and 300 ft. wide. It is equipped with nine movable elevators and seventy-five "Hunt" automatic railways. The unloading capacity of this plant amounts to 7,000 tons per day.

This system is not suitable for large or friable coal on account of the rather rough discharge.

The origin of this device is somewhat curious. The first "Hunt Automatic Railway" was built in 1871, and appears to owe its existence to a strike of coal wharf operatives. History does not state where this first railway was erected, but it was doubtless in or about New York, the home of the C. W. Hunt Automatic Railway Co.

UNLOADING OF RAILWAY WAGONS

(Continued)

CHAPTER XXXV

UNLOADING RAILWAY WAGONS BY MEANS OF TIPS OR HOISTS

THE method of unloading railway trucks described in this and the preceding chapter is without doubt one of, if not the most rational means of handling material, because the operation itself is the simplest and quickest, and by its means the greatest quantity can be handled in the shortest space of time, provided the mechanical appliances which give life to the method are economical and up to date.

The appliances, which are hereafter described, are classed under three headings. Each of these three different types of tips is suitable for a different purpose, mainly depending upon local conditions, such as the height of the railway siding or quay above the water level in the port, river, or other destination of the material to be unloaded. The three types of tips are the following :—

- A. Tips which Unload Below the Level of the Railway Lines, also called Gravity Tips.**
- B. Tips which Unload on the same Level as the Railway Lines, or Slightly Above.**
- C. Tips which Unload Above the Level of the Railway Lines, generally called Coal Hoists.**

The type B is more particularly used for unloading coal, etc., from trucks in factory yards, whilst types A and C are generally used for loading ships with minerals and cargo or bunker coal.

A—Tips which Unload Below the Level of the Railway Lines.—It is obvious that the operation of unloading trucks for the purpose of depositing the contents below the rails can be performed without the expenditure of power, as the weight of the coal itself is sufficient to tip the truck, and to use the inertia either directly or after being stored in accumulators to right the truck after emptying.

Tips of this type are most economical when the rails on which the trucks arrive at the tip are high above the point where the coal is to be received. This condition obtains but rarely in factory yards, but is frequently met with on the banks of tidal rivers. In such cases these tips are ideal appliances, as no driving power is required, and the material is conveyed to its destination (generally ships) by gravity.

The truck when tipped is in such a position that the front edge of the platform is 6 to 8 ft. below the level of the rails, so that if the rails are not above the ground level an excavation of 20 to 30 ft. below the rails may be necessary, in order to receive and further dispose of the material by other mechanical means (see Fig. 812). Such excavations add so much to the capital expense, that tips of this type are rarely economical unless, as stated above, the rails are well above the ground level.

The following are a number of examples of coal tips of this class :—

The Old Newcastle and Cardiff Tips are here described on account of their historic interest. They have done good work in the past, but are now generally superseded by tips of later type. They are only applicable where the trucks are on the wharf at a high level, or where the railway lines are raised on staiths, from which elevation the coal is deposited by gravity down the shoot into the vessel. Hopper-bodied wagons, or wagons with hinged end doors, are employed to load into the shoot. In Newcastle the former wagon is more often used, and in Cardiff the latter.

Fig. 804. Balanced Gravity Tip of the Old Cardiff Type.

These balanced tips consist of a suspended cradle or platform *A* (Fig. 804), sliding in vertical guides, and supported by balance weights *B* connected to it on either side by chains passing over pulleys *C* at the top of the framing, upon which are brakes *D* for controlling the motion of the cradle. The balance weights are sufficient to raise the cradle and empty wagon, but are not equal to the load when a full wagon is upon the cradle. The contents of the wagons *D* are discharged through an end door into an inclined shoot *E* extending over the ship's hatchway, and sometimes having screens at the bottom for separating the dust from the coal. The brake is then released, and the cradle with the empty wagon rises to the top again, the wagon is run off into a siding, and the

cradle is then ready to receive another wagon. Crane *N* and lowering device *P* are employed in order to minimise breakage.

By the use of tips of this construction a height of 9 ft. is lost by having to lower the cradle sufficiently to tip the wagon. A gradual increase in the size of the ships to be loaded rendered it necessary to prevent this loss of effective height in the tips, in order to raise the shoots to the level required by the increased height of the decks of the ships. Instead of lowering the cradle, therefore, the tail end is hauled up by a winch worked by hand, thus converting it into a tip discharging on the level of the rails instead of below. This tedious process was subsequently superseded with great advantage by hydraulic machinery, consisting of a simple Armstrong crane cylinder with a 9-in. ram and double pulley connected to the tipping chain. This system has been adopted in reconstructing the old balance tips at both the east and west docks at Cardiff. The first balance tips constructed at the west docks received the wagons on the cradle at a level of 18 ft. above the quay, but the increased size of the ships to be loaded has necessitated raising the railway and the framing of the tips 3 ft. higher, making the level for the wagons at the west dock 21 ft. above the dock coping, or 22 ft. above the water. The coal tips at the east dock were originally constructed at this higher level, but in consequence of such large vessels being loaded there, the height of the additional tips constructed has been further increased by 6 ft., giving a height of 27 ft. above the coping.

As it is necessary to adjust the level of the shoot to the actual height of each ship, in order to reduce breakage of coal as much as possible, the heel of the shoot is attached to the frame of the tip in order that it may slide in a vertical groove. The shoot is carried by adjustable chains with balance weights and winches, so that the inclination as well as the height of the shoot can be changed if necessary.¹

This short history has been given here for the sake of completeness, although the converted tips really belong under heading B.

Hydraulic Tip at Dortmund.—A hydraulic coal tip of some interest is at work in the harbour of Dortmund in Germany. It is on the Schmitz-Rohde principle, and was built by Friedrich Krupp, Grusonwerk, Magdeburg. This tip consists essentially of a platform swinging on a horizontal axis. The coal trucks are pushed on to this platform and tip with the latter, emptying themselves over the end into the barge. The apparatus works without the expenditure of outside power, so that there is no necessity for a motor. The principle is to utilise the energy due to the weight of the contents of the truck when lowered, and to store it in an accumulator, to be used again for raising the platform and truck when the latter is empty.

This is an improvement on similar installations in which this energy is lost by absorbing it in a brake, as in that case motive power must sometimes be provided for lifting the truck. The tip can be used for the rolling stock of all the lines which bring coal or coke to the harbour of Dortmund, and for loads of 10 to 15 tons, the only condition being that the trucks are fitted with hinged end doors. Figs. 805, 806, and 807 illustrate the tip. *A* is the platform which swings round the trunnion *C*. The forward end of the platform is suspended by the hydraulic ram *F* of a movable supported cylinder *B*. To the other end of the platform a balance weight is attached. The cylinder *B* communicates with an accumulator *D*, the connection between the two being controlled by a valve and manipulated by a lever *C*, and in the control of this valve lies the whole manipulation of the tip.

¹ This description is taken from a paper read by Mr John M'Connachie before the Inst. Mech. Eng. See *Proceedings Inst. Mech. Eng.*, August 1874, pages 125 to 130.

The action of the tip is as follows:—

As the truck is being pushed on to the platform its two front wheels depress two

Fig. 805. Plan of Coal Tip at Dortmund.

levers, which action releases two strong hooks that hold the axle of the front wheels. This is seen in Fig. 806. The hooks and the levers manipulating them are concealed



Fig. 806. Longitudinal Elevation of Tip at Dortmund.

below the platform when out of use, and do not therefore interfere with the brake tackle under some of the trucks. The truck and the levers holding it are coupled

to the axle of the platform, not rigidly, but by means of volute springs to reduce the impact. The truck is allowed to move into a position in which its centre of gravity is on the water side of the centre of the platform. The weight of the load causes a pressure in the cylinder *B* of about 300 lb. to the square inch. The pressure in the accumulator is, however, only about 255 lb. The valve is now opened, and as there is a difference in the pressure of cylinder and accumulator of 45 lb. to the square inch, the weight of the truck pushes the ram into the cylinder, thereby lowering the platform, and the truck begins to discharge. During the tipping process the centre of gravity of the truck alters its position in such a way as to increase its leverage. The momentum of the load does, however, decrease as the load of the truck is getting less. At the angle of 45° the platform and truck have reached their maximum travel, at which the latter is empty. The speed of the descent can be regulated by throttling the communication between hydraulic piston and accumulator by means of lever *C*, which is closed altogether as soon as the lowest position is reached.

The coal as it leaves the truck falls into a shoot which forms an extension to the platform, the sides of which, to prevent waste, are somewhat higher than the truck. The end of the shoot can be so adjusted as to let the coal fall gently into the ships or barges which are to be loaded. As the load on the ram *F* becomes less towards the end of the operation, the pressure is reduced to about 210 lb. When the valve is now reopened the surplus pressure in the accumulator is sufficient to raise the platform into its original position. The valve is manipulated by a lever *C* over the accumulator on that part of the structure which is not movable. From

Fig. 807. Cross Section of Tip at Dortmund.

the same spot a second lever can be used which actuates another valve, which allows the water to escape from the cylinder *B* to the open, in case the load in the truck should not be sufficiently heavy to force the water out of *B* into the accumulator. As the momentum decreases during the tipping process, the valve must be closed almost immediately after the platform has begun to descend in order to economise the pressure in the accumulator. Finally, there is a safety valve which opens automatically in case of extreme pressure in cylinder *B* through the valve having been closed too soon. This valve admits the water into the accumulator. The plant is provided with a hand pump, which is used when the cylinder and accumulator are first filled, and also to replenish any loss through leakage, and also in cases where the cylinder *B* has to be relieved into the open as stated above. A mixture of glycerine and water is used in the apparatus to prevent freezing.

It takes five men to manipulate the tip. One operates the valve and lever *C*, two are placed in the shoot and go up and down with it to regulate the discharge by means of two small winches, whilst two push the trucks on to and off the platform.

As the goods station is on the same level as the quay wall, the coal train is taken up a sufficient incline, and there is a slight fall from the point about half-way between the

Fig. 809. Cross Section of Tip at Ruhrort Harbour.

Fig. 808. Longitudinal Elevation of Tip at Ruhrort Harbour.

platform and the tip, so that the trucks run down by their own gravity to the latter. They pass a turntable on their way to and from the platform of the tip.

The Coal Tip at Ruhrort Harbour.—This is very similar to the tip just described,

and was also built by Krupp, of Magdeburg. It is illustrated by a longitudinal and cross section in Figs. 808 and 809.

Two perspective views of the same are given in Figs. 810 and 811. The con-



Fig. 810. Perspective View of Tip at Ruhrort Harbour.

struction is almost identical with that of the tip at Dortmund, and needs, therefore, no further description.

A similar appliance to the last mentioned is the work of Rudolf Dinglinger, of Coethen, Germany. It is illustrated in Fig. 812. This plant acts almost precisely in the same manner as the last. The valve and hand wheel, which are visible in the

illustration, break and open the communication between the hydraulic cylinder and the accumulator (the latter not being shown). This device is intended for unloading coal in factory yards, and disposing of it by elevator either into the coal stores or into the bunkers

Fig. 811. View of Tip at Ruhrort Harbour in Unloading Position

over the boilers. In many cases it is necessary to provide such a tip with a coal-breaker between the hopper and elevator.

Coal Tips at Bethune.—Unlike the tips previously described, which tip and empty themselves on a transverse axis, the tip of the Compagnie des Mines de Bethune

turns on a longitudinal axis. The installation, which is illustrated in Fig. 813, was erected for the purpose of quickly discharging coal, brought from the Marles Colliery, at a small expenditure of driving power. As will be seen from the illustration, the quay wall, which has been constructed by the Marles Colliery Co., is at a sufficient height above the water level to allow of a discharge from the quay to the barges by gravity. This automatic tip is the design of Messrs Taza & Villian, of Annezin. It consists essentially of a substantial platform having a frame of wrought iron, which supports a portion of a railway track of standard gauge. Loaded trucks are pushed on to this platform, and then a very small expenditure of power is necessary to set the tip in motion, whereupon the coal is deposited in an inclined shoot, which leads, by means of an additional piece of spouting, to the river. As soon as the coal has been discharged, the tip returns with the truck to its original position, when the truck is pushed off the

Fig. 812. Tip for Power Stations and Factory Yards.

platform by the next full truck. This process is an exceedingly simple one, but, as in the case of the appliances previously described, some precaution needs to be taken to prevent a shock, and also to provide for an automatic return of the tip to its original position. To this end a hydraulic brake has been constructed in conjunction with a balance weight. This brake consists of a cast-iron cylinder, 16 in. diameter, which is erected beneath the platform within the quay wall. A piston which fits the cylinder is connected with the platform of the tip by a connecting rod. Both ends of the cylinder are connected to the hydraulic main, the outlets being controlled by valves. Thus when the platform is being lowered during the discharge of the contents of the truck, the piston forces the water out of the cylinder, and by regulating the outlet by means of the above-mentioned valve the process of lowering can take place without shock. The return movement of the platform to its level position is controlled by the balance weight. The truck with its load of 10 tons of coal is pushed upon the platform, which is, by the way, supported upon two

trunnions 8 in. in diameter, which are placed slightly out of centre with the platform to give it a natural inclination to sink towards the waterside. The balancing device consists of two weights secured by iron bracings to the lower portion of the platform. The total weight of the two is 5 tons, or somewhat more than the weight of the empty truck. As soon as the load has left the truck there will be a tendency for the counter-weight to replace the platform in its original position.

During the return of the platform, the hydraulic cylinder and piston are again brought into action to prevent a too quick return of the platform, and thus avoid shock. The railway trucks are specially constructed for this particular purpose, and have hinged side doors instead of the more usual end doors. The whole load of 10 tons is discharged

Fig. 813. Tip at Bethune.

into a shoot which is of sufficient capacity, the outlet of this shoot being so contracted as to let the coal out into the barge in a gentle and more or less uniform stream.

It is generally so arranged that the same time is allowed for the coal to empty itself out of the shoot into the barge as it takes to bring back the empty truck into its original position and replace it by a full one. A number of capstans have been erected at the quay by means of which the barges can be quickly put into position for loading. One man is sufficient to operate the tip. Two such tips are now at work at Bethune, and as each is capable of dealing with twenty-five trucks of 10 tons each per hour, 5,000 tons per day of ten hours can be handled, and a speed of five wagons in ten minutes has been accomplished. These tips have the undoubted advantage that the empty trucks can never be in the way of the full ones, as all trucks, both full and empty, are moved in the same direction and on the same road.

A device similar to the Bethune coal tip was erected by the Société Charbonnière,

of Lens;¹ also by the Bruay Mining Co., Calais,² in connection with their loading basin at the north of Bethune. The capacity is rather less than in the case previously described, as it will only handle seventy wagons of 10 tons each per day.

The Noeux Co.'s Tip.—This device, which is again similar to those just described, is illustrated in Fig. 814. It has been used at the dock of the Noeux Co., in connection with the canal of La Bassée à Aire.

There is a fixed hopper or frame formed of two ribbed cast-iron cheeks solidly bolted to the wall of the wharf, on which is fixed a crane for handling a movable shoot. This movable shoot is connected to the fixed hopper by a spout which can be turned in any position around a vertical axis, and distributes the coal over the area thus commanded. The trucks are of special construction, and their bodies consist of three boxes of a capacity of $3\frac{1}{2}$ tons each, which are tipped separately.

Fig. 814. The Noeux Co.'s Tip.

On the side next the hopper the boxes are provided with doors hinged horizontally at the top, and engaging in clips which are fastened a little back upon the ends of the car. At the bottom of this door two pins are fastened which work laterally, and are caught, when the box rests on the truck, by two dogs attached to the sill.³ With this arrangement, when the box is raised from the back, the pins on the door are gradually set free from their dogs, and at a certain point the door becomes unfastened and opens for the passage of the coal. On the return, when the box is empty, it drops back on the under frame, the pins catch under their dogs, and the door is fastened. At the

¹ A description of this arrangement will be found in the *American Engineer and Railroad Journal*, February 1894, page 70.

² This appliance was described in the *American Engineer and Railroad Journal*, March 1894, page 112.

³ A description of this arrangement will be found in the *American Engineer and Railroad Journal*, March 1894, page 112.

Noeux station the boxes are raised by means of a hydraulic ram, whilst at the loading wharf they are manipulated by an ordinary crane.

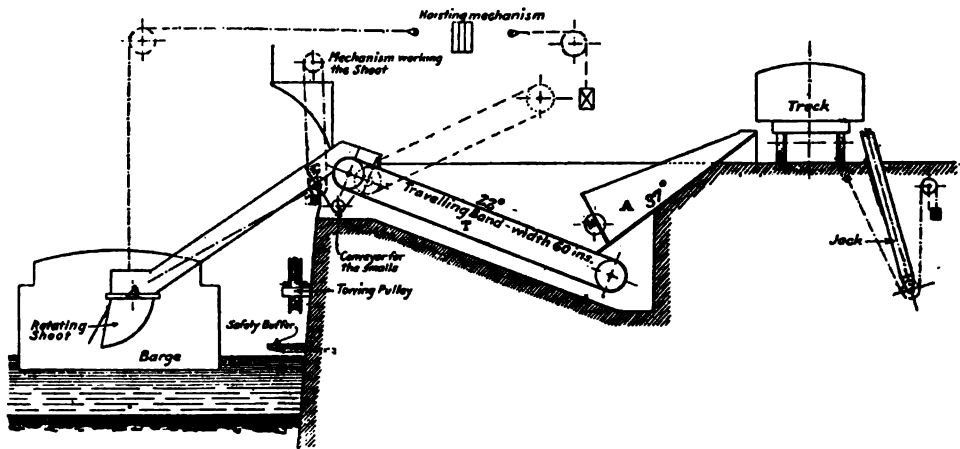


Fig. 815. Coal Tipping Arrangement at the Dourges Colliery.

The Coal Tip at the Dourges Collieries is a further development on the foregoing lines, and was described by M. Prudhomme, the chief engineer, before the Société de l'Industrie Minérale.

The problem to be solved was to empty, in one operation, 15-ton trucks, and transfer their contents into barges, the difference of level between the bank and the water being only 10 ft.

It may be stated at the outset that all the machinery is worked by electricity.

The plant consists of a device for tilting the coal trucks (see Fig. 815), driven by electricity through the medium of belting and gears reducing the speed. A chain fixed at the point *o* passes round pulley *R*, then over the pulley *R*₁, which is keyed to the shaft. A counterweight imparts the necessary tension to the chain. The jack rises and sinks with the pulley *R*; it is guided by rollers, of which one, *G*, is in contact with cam *I*. The cam surface is so arranged that the head of the lever follows very closely the bottom corner of the truck in the arc of a circle, which it describes while being tilted. The descent of the wagon is effected by its own weight and that of the jack. The movement is regulated by a brake, which is sufficiently powerful to retain even the loaded truck body in any position. The tilter is furnished with a contact which breaks the current as soon as it has attained the end of its path.

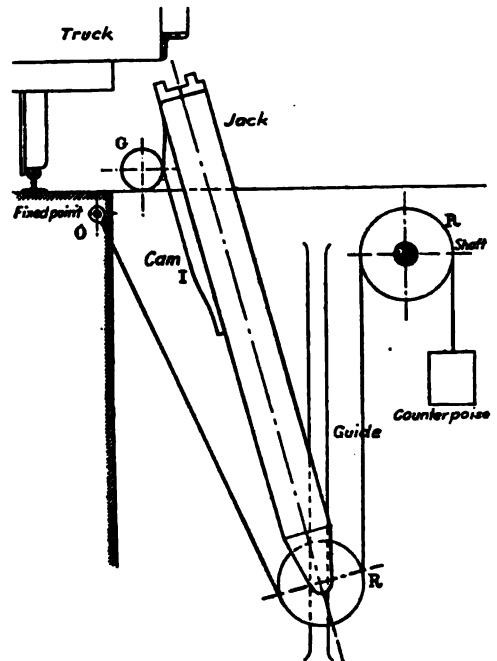


Fig. 816. Larger Scale Detail of Fig. 815.

Shoot A is a fixture (see Fig. 816), and can accommodate the 15 tons of coal from one truck. At the base of this shoot there is an outlet valve which regulates the passage of the coal and is manipulated by the wheel v. A travelling belt discharges the coal upon a screen c, while a screw conveyor carries off the smalls which fall through, and the coal passes on to the loading shoot proper, which is furnished with a rotating mouthpiece similar to that of the last installation. This outlet is suspended by a flat steel rope, by means of which it can be raised or lowered.

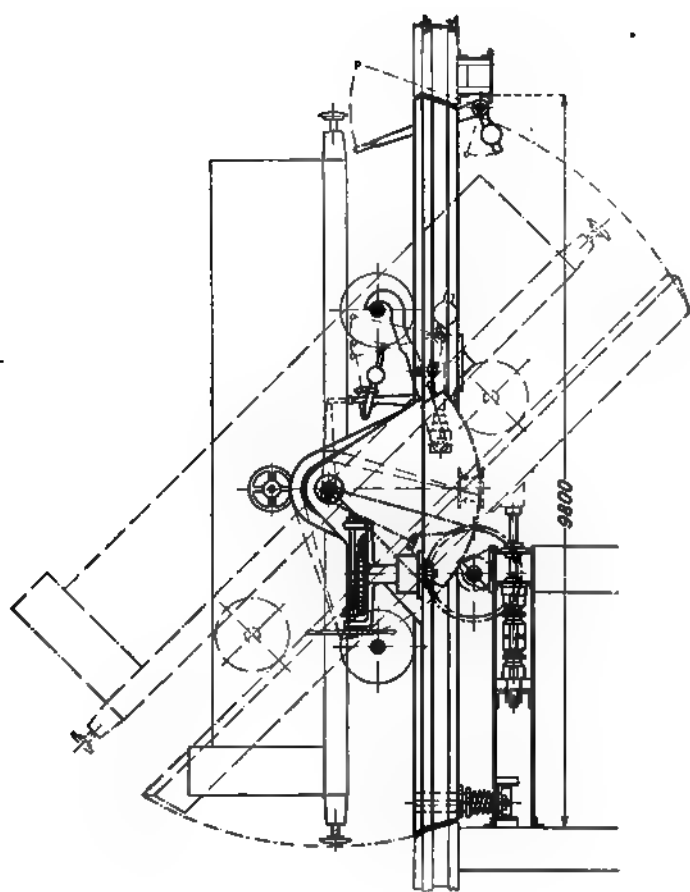
Coal Tip Built by Pohlig.—Another device which comes under this heading is that built by J. Pohlig, of Cologne, and illustrated in Fig. 817. The truck is held in position by a chain at the tail end, whilst the front buffers rest against a support specially constructed for this purpose, to take the weight without straining the buffer springs. Unlike the tips previously described, the one under consideration is manipulated by a band brake. The end of the cradle is weighted to bring it back to its original position when the truck is empty. The band brake is of such power that

Fig. 817. Tip Built by Pohlig.

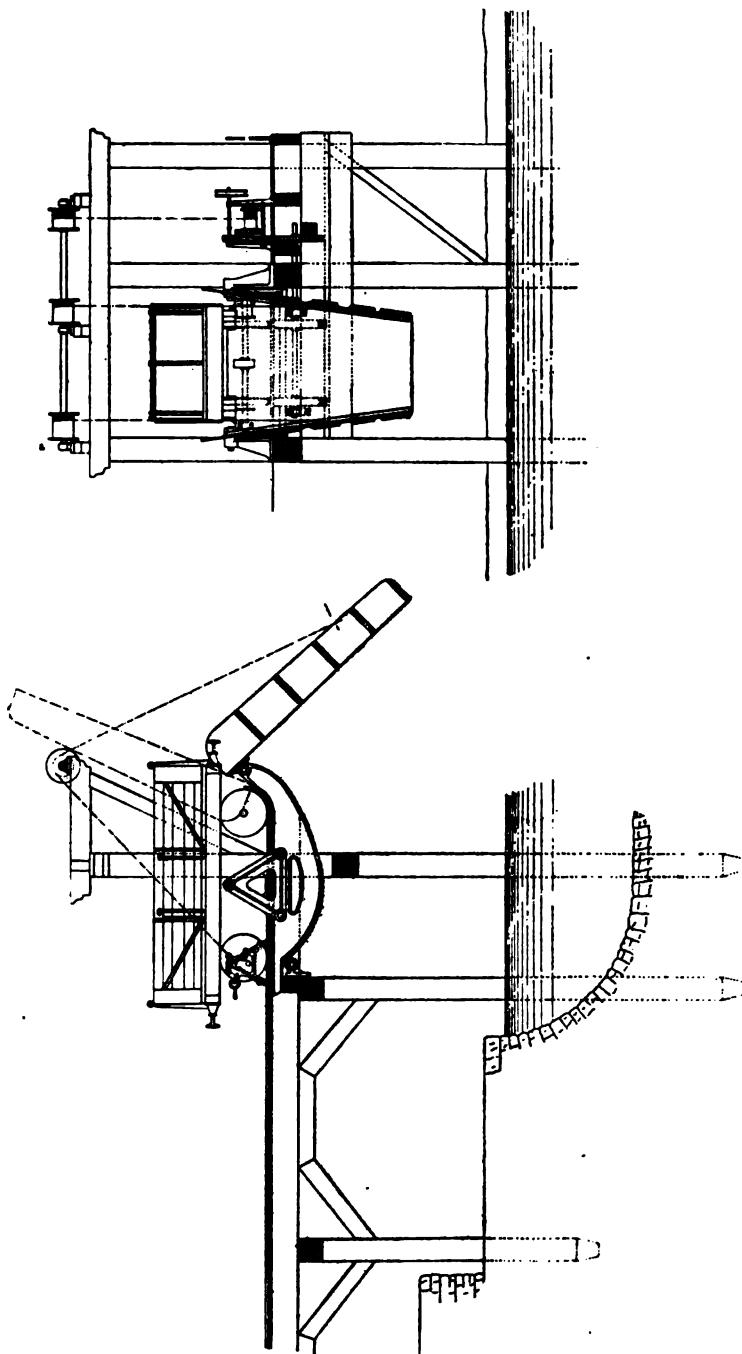
the truck can be held in any position. The tip is also fitted with a hand winding gear to be used if, in exceptional cases, the truck should not go back to its original position. Another and later type of tip by the same firm is shown in Figs. 818 and 819.

The Stevenson Coal Tip.—This tip is illustrated in Figs. 820 and 821, and is also manipulated by gravity. The mode of working is to run the truck on to the tip, which is kept in a horizontal position by means of a powerful brake. The position of the truck is such that its own weight will overbalance it as soon as the brake has been released. After the discharge of the truck it returns automatically into its original position. It is fitted with a shoot which can be housed out of the way when not in use, or the angle of which can be adjusted to suit the circumstances.

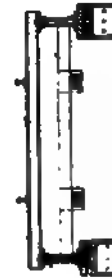
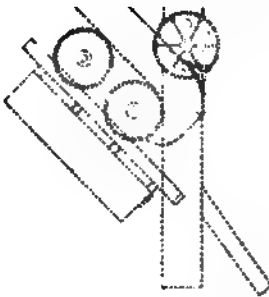
Figs. 822 to 824 represent another type of Stevenson's coal tip very similar to that just described. The illustrations show the appliance in plan and elevation, and the tip is shown, in Figs. 822 and 823, in its discharging as well as in its horizontal position. This particular tip is arranged to overhang the quay wall, in order to get the discharge of the tip right on the barge to be loaded.



Figs. 818 and 819. Modification of Tip shown in Fig. 817.



Figs. 820 and 821. Stevenson's Coal Tip.



Figs. 826 to 827. Longitudinal Elevation and Cross Section of Coal Tip built by Stevensons, Ltd., of Preston.

wagons of 10 to 12 tons' capacity, and is so designed that they can, under the easy control of a powerful brake, be lowered safely by gravity right down to, and even into, the ship's hold before they are discharged, thus minimising the breakage of the

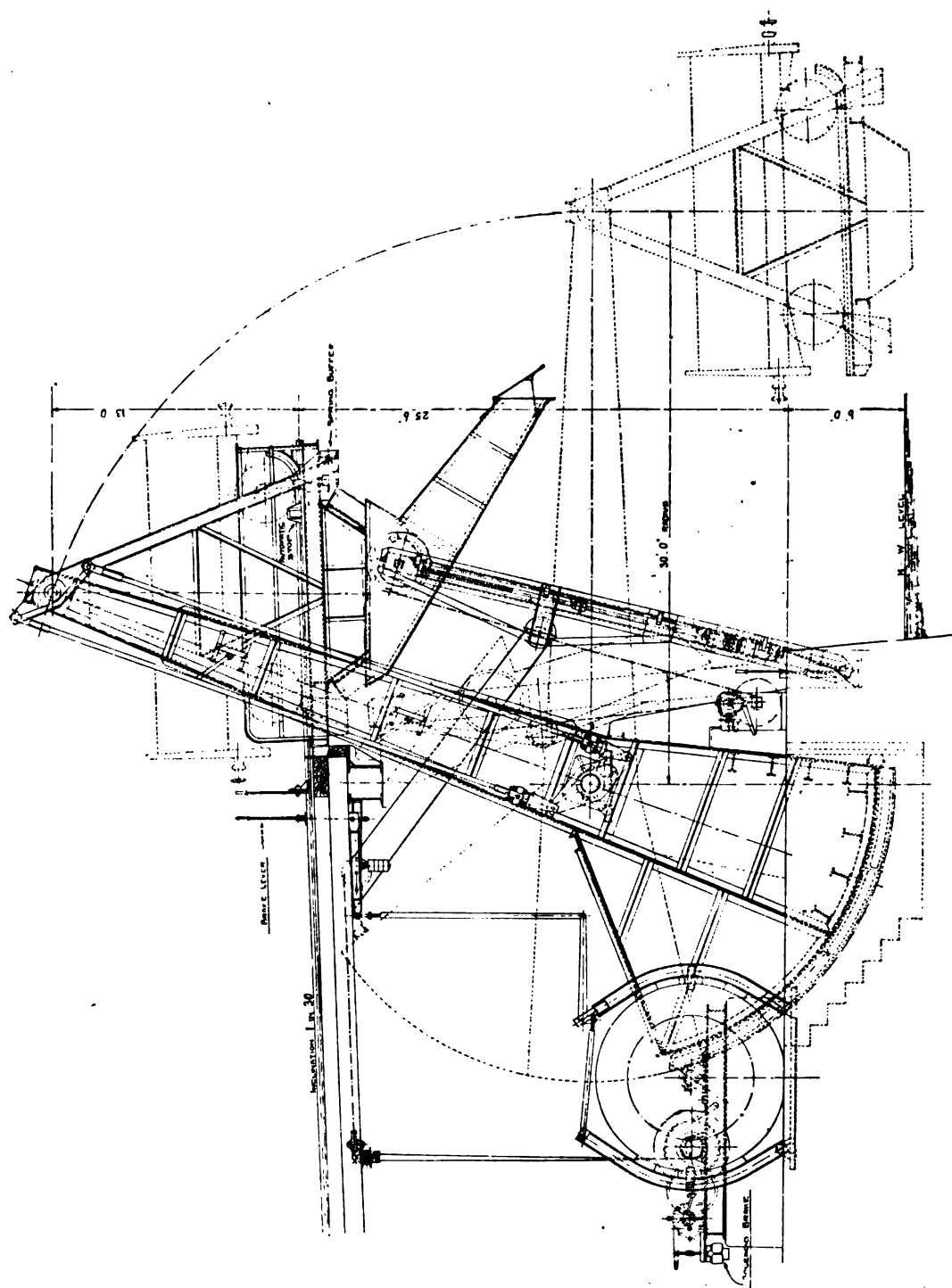


Fig. 828. Gravity Coal Shipper at Sunderland.

tender coal handled at that port. The empty wagons are then brought back by means of the counterbalance weight, no machinery being required under ordinary working conditions. Should it be found necessary to return part of the contents of a wagon when completing the loading of a boat, this is done by means of a small electric motor with gear, provided for the purpose. The apparatus has now been working successfully for a considerable time, and is capable of dealing with 500 tons of coal per hour.

B—Tips which Unload on the same Level as the Railway Lines, or Slightly Above.—Tips of this description are manipulated by raising one end of the truck in order to unload it, the reverse process having been followed with the tips previously described. There one end was lowered beneath the level of the rails for the discharging process, which allows of unloading with practically no expenditure of driving power. Tips that unload on the same level as the rails must in all cases be actuated by hydraulic or other power.

Tips of this type are made of two kinds: either a portion of the rails is laid on a platform, which latter is raised mechanically at one end to unload the truck which is held in position upon this platform, or the truck remains with one pair of wheels on the ordinary track, whilst the other end of the truck is raised by lifting the back axle. The former type is more costly, but it has the advantage that the trucks can be tipped to a steeper angle without the buffers coming in contact with the rails, whilst with the latter type the buffers will touch the rails before the platform of the wagon is at a sufficiently steep incline for some materials, such as damp coal, to clear the truck without assistance.

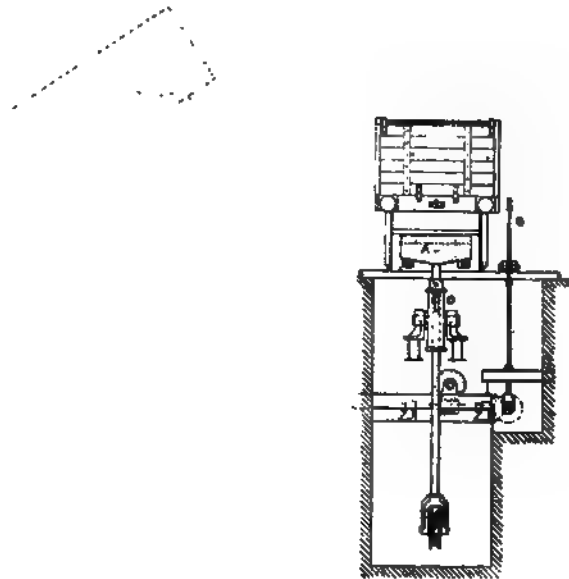
What has been said in reference to the disposal of the material with regard to tips of type A applies also here, with the difference that if an excavation is necessary it may only have to be 15 to 20 ft. deep, instead of 20 to 30 ft. in depth, but such an excavation is still a very costly undertaking which reduces the usefulness of the tip more or less if economy is studied.

The Power Tips of the Great Western Colliery Co., Pontypridd.—The annexed illustrations, Figs. 829 and 830, are the design of Mr Davison, engineer of the Great Western Colliery Co., Pontypridd. The apparatus is shown in a longitudinal and cross section. The trucks to be emptied by this tip must be provided with hinged end doors.

The main feature of this tip is that it can be operated by a motor or by a belt from any existing shaft. The rails remain unbroken, and the apparatus can be used without interfering with the traffic on the siding. It is evident that there are many cases in which such a tip can be used with great advantage. It will be seen from the illustration that the rear axle is brought over the ram-head A when the lever B is thrown over, which causes the friction clutch to engage with the worm shaft actuating the drum, and thus winds the chain which lifts the ram. Radial rods C are fixed to the ram-head and prevent the truck from moving out of its position during the lifting process. The ram passes through a cast-iron sleeve D with trunnions guiding it in the course given by the radial bars, and when the truck is tipped the lever is moved to the opposite side. This causes the reversal of the gear and the consequent lowering of the truck on to the rails again. The time occupied in tipping the truck is about one minute. These tips are built by Sheppard & Sons, Ltd., of Bridgend.

The Double Tip at the Cardiff Corporation Electricity Works.—Where it is more convenient for any reason to manipulate tips from above instead of below, a very useful device is the one here described and illustrated in Fig. 831. It was designed

by Sheppard & Sons, Ltd., Bridgend, to meet special requirements where space did not permit of the underground type being installed. The advantages of such an arrangement



Figs. 829 and 830. Tip in use at the Great Western Collieries.

for more general use are obvious. Working parts are readily accessible for examination and repairs, whilst the obtainable angle of tip is such that even wet material may be freely

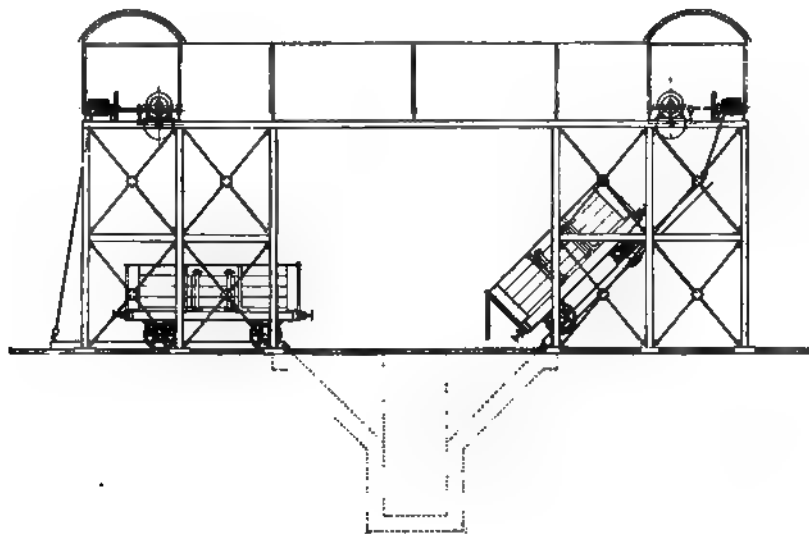


Fig. 831. Double Tip at the Cardiff Corporation Electricity Works.

discharged. This is not always possible with the non-platform ram tip, in which the angle of tip is limited by the buffers coming in contact with the permanent way. This

system of end-tipping has also an advantage over some others, inasmuch as the whole strain is put upon the wagon through the two axles, so that there can be no damage to the wagon as would be the case if lifted by the buffers, and the springs and axle-boxes cannot get out of position.

The tip consists of the usual platform hinged at one end, and fitted between the rails to give a clear way for the wagon to pass over when not in use. This platform is double the length of the wheel base of the trucks; thus there is a leverage of two to one of the dead weight to be lifted, in favour of the gear. The back axle of the truck is engaged by a cross member of the platform, having two wrought-iron plates fixed on each side, which prevents the axle slipping off as the truck is raised. Plates are also fitted on the framing of the cradle under the front axle, so that, if necessary, the whole truck can be lifted off the rails to obtain a sufficient angle for emptying. The winding rope travels across the drum, and thus the angle of the rope to the cradle is never excessive.



Figs. 832 and 833. Tip at the Brentwood Gasworks.

The simplest form of drive is from a countershaft by open and cross belt. The countershaft is driven by a motor of 10 H.P., the power required to tip a 12-ton wagon. In practice, two truck tippers are often provided as in the illustration, one on either side of the hopper, so that if the end door of the wagon comes in the wrong direction for the one tipper it would be right for the other. A turntable in conjunction with one tipper would obviously answer equally well, though the difference in cost between a well-made turntable and the tipping apparatus would be trifling, whilst the first-named would entail more labour in operation.

Tip at the Brentwood Gasworks.—The installation illustrated by Figs. 832 and 833 is at work at the Brentwood Gasworks, and as the coal is taken in there at the rate of only 10 tons, or one truck-load, per hour, the slower working tip answers the purpose quite as well as one fitted with a more powerful pump, and consequently having a quicker action. The hydraulic lifter and pump were built by the Leeds Engineering and Hydraulic Co., Ltd. The pump is a very small one, and is always at work when coal is being unloaded. This does not cause any waste of power, as the water only

circulates between pump and tank. When the truck is ready to be tipped the water from the pump is forced into the hydraulic cylinder by turning a lever which controls a valve, when the ram slowly lifts the back portion of the truck off the line, whilst the front wheels rest against stop-blocks. The coal begins to discharge from the removal of the tail-board till the truck has been lifted to an angle of 45° . To lower the truck on to the line the water is allowed to escape from the cylinder into the tank out of which the pump is fed. This can be done slowly by carefully opening the valve.

Coal Tip of Pohlig.—A powerful platform tip is that built by Pohlig, of Cologne, shown in Fig. 834. The platform is pivoted at its fore end, and is raised above the level of the ground by hydraulic force applied to its centre. The truck, of course, moves

Fig. 834. Coal Tip as built by Pohlig.

with the platform until it is tilted at an angle of 45° , at which angle the rest of the material is discharged into the hopper or other receptacle on a level with the line. To minimise the expenditure of power, the weight of the platform is balanced by counter-weights. In other respects this platform is designed exactly on the plan of the cradle used in the other automatic tipping devices built by the same firm, which are described elsewhere.

To prevent a sudden drop of the heavy platform and its truck, which might happen if some portion of the gear were accidentally to give way, this tip is provided with a safety brake which holds the truck and platform so that in case of breakage it cannot move either up or down any faster than at its normal speed.

Tips in Factory Yards.—For use in factory yards the tips previously described have the inherent disadvantage that, unless the railway siding is raised on some structure above the ground level, it is difficult to dispose of the material unloaded by them, as

mentioned before, without the use of large pits in the ground to accommodate, or form in themselves, receiving hoppers for the contents of the trucks, and also to accommodate an elevator well or some other device for getting the material out of these hoppers again. Now such underground receptacles are, as every one knows, a source of endless trouble, owing to the ground water which in some cases makes their use all but impossible without sinking iron tanks into the ground. This being so, any tip which discharges a little higher above the ground will save so much excavation, trouble, and expense.

These circumstances were the incentive which led Professor Aumund, of Dantzig,¹ to design a tip which is on an entirely different principle.² He sets himself the task to construct a tip which discharges high enough to altogether avoid, or greatly lessen, the necessity of excavated receivers, and one which dispenses also with heavy platforms and

Fig. 835. Portable Curved Tip at the Hague Gasworks.

gears, and which might be used independently of costly foundations. It is an essentially portable tip, which he names "Curved-tip," as the truck is raised on to the curved rail track until it is in such a position that it will unload by an end door. Tips on this principle are not only built portable and stationary, but also with a revolving upper part or turntable, so that the trucks may be discharged at any angle with the railway track.

An example of a typical curved tip is shown in Figs. 835 to 837. The first illustration shows a perspective view of a truck at the point of discharge, whilst the two latter show side and end elevation of the same tip. It will be seen from the illustrations that the

¹ From an article by Professor Aumund in the *Zeitschrift des Vereins deutscher Ingenieure*, 1909, page 1437. The Author is indebted to Messrs Pohlig, of Cologne, the makers of this type of tip, for the illustrations.

² Although some of these tips discharge considerably above the line, it has been thought advisable not to divide these descriptions under this and the next heading, though that course would have been strictly correct.



Fig. 886 and 887. Diagrams showing Principle of Portable Curved Tip.



Figs. 838 and 839. Curved Tip at the Harbour at Bremen.

essential feature is the curved rail track, which in this case is portable, running on wheels and on a standard gauge rail track. The curve of the rail track is so chosen that the truck first ascends very gently, and at the extreme end the buffers of the largest truck do not touch the rails. Figs. 836 and 837 show that the truck is first pulled upon a low bogey, to which one axle of the wagon is secured, and also in the highest position where it delivers the load. A capstan, which is part of the gear of the tip, first pulls the



Figs. 840 and 841. Tip at the Liège Ga. works.



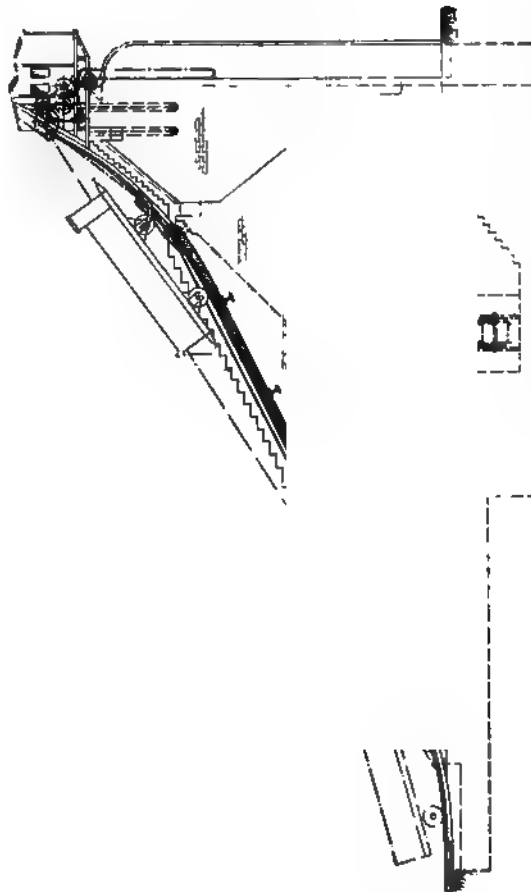
truck to be emptied on to the bogey, and as soon as it is in that position the hoisting gear is started, and immediately the chains begin to pull, two powerful hooks engage automatically with the front axle of the truck. These two chains are shortened by the hoist until the whole truck with the low bogey have reached the highest point. The unloading takes place between the angles of 45° and 55° . The capacity of such a tip is 150 tons per hour, and the electro-motors manipulating it from 15 to 25 H.P., varying with the height of lift. The power consumed for 10 tons unloaded, inclusive of the

capstan, is .3 kilowatt. After the truck is discharged it is allowed to descend into the first position (see illustration), where it leaves the bogey on its own account, as the hooks holding it are automatically released as soon as the lowest position is reached. It is usual to have a branch siding for the empties so that the progress of the full truck is not impeded and the tracks are laid with a slight downward incline. Figs. 838 and 839 show the same tip, but stationary instead of on wheels, at Bremen Harbour, where it has been installed by the North German Lloyd Co.

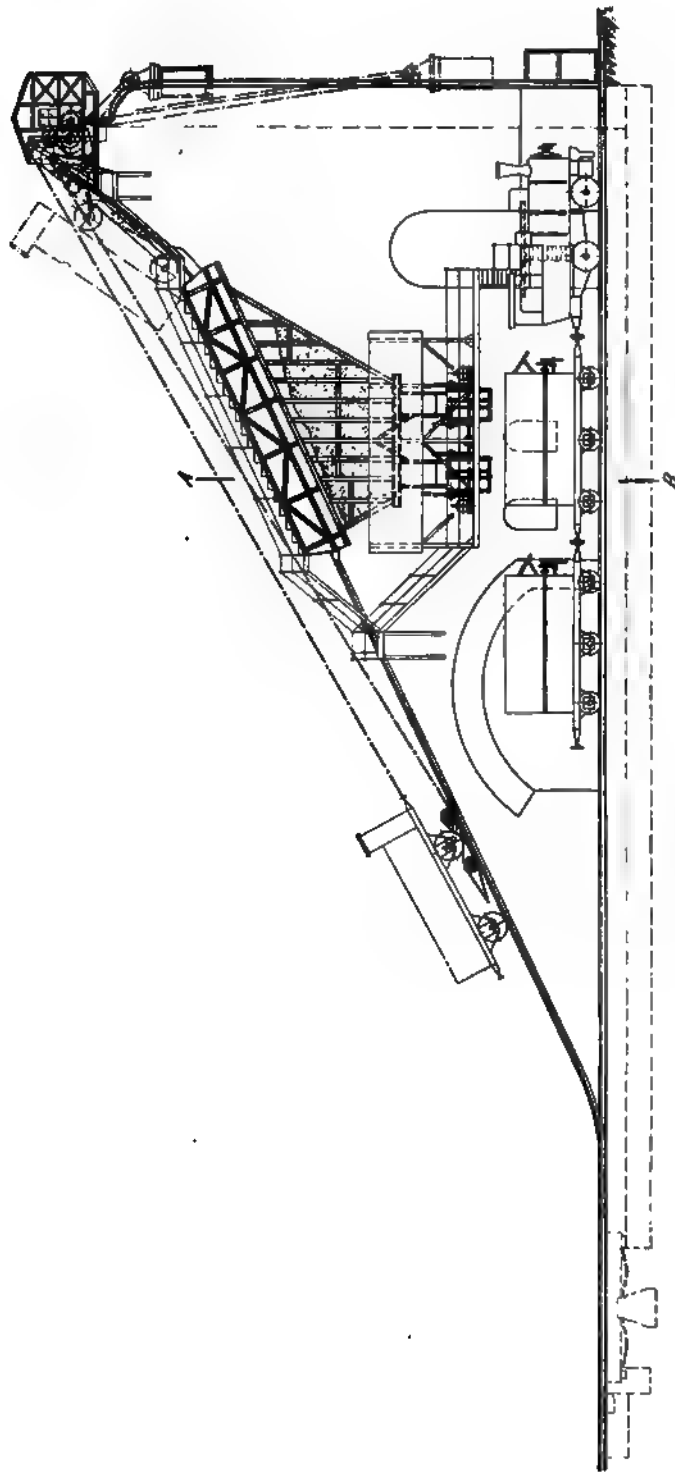
Another construction is to have the curved bed for the tip formed of a block of concrete or masonry, as shown in Figs. 840 and 841, with a motor house and driver's stand at the top. This installation is at work at the gas-works of Liège. The stationary appliances just alluded to are worked in identically the same manner as the portable ones, but they lend themselves better for a somewhat greater lift, and thereby save excavation for the further disposal of the material, as the trucks are lifted frequently by these appliances 5 to 10 ft. above the rail level.

As regards cost of unloading, from actual figures derived from the installations, it may be seen that if 240 tons have to be handled daily, the capital expenditure for such a tip is fully warranted from a commercial standpoint.

The tip shown in Figs. 842 and 843 is the same, but for a greater lift. Here the small



Figs. 842 and 843. Curved Tip at the Reicholz Electricity Works.



Figs. 844 and 845. Curved Tip for Iron Ore and Limestone at a Westphalian Blast Furnace.

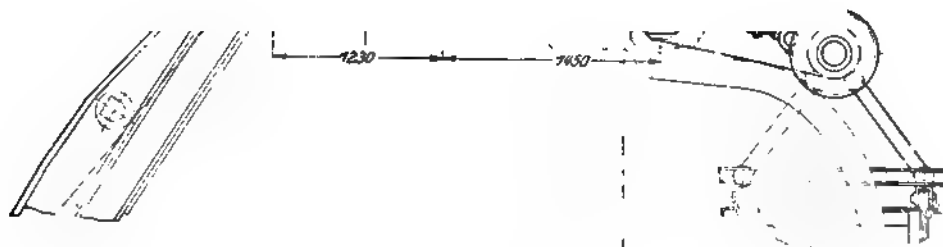


Fig. 846. Side Elevation of Winding Gear for Curved Tip.
(The dimensions are in millimetres.)



Fig. 848. Plan of Fig. 846 (Section A B).
(The dimensions are in millimetres.) *

Fig. 847. End Elevation of Fig. 846.

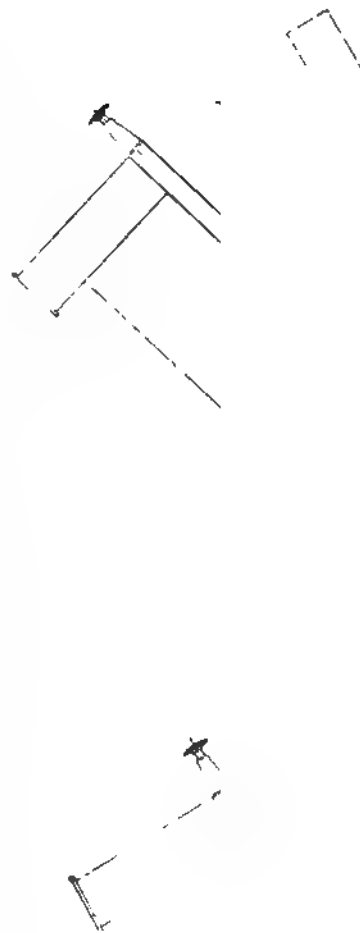
bogey is let down over an inclined portion of the track at an angle of 30° , and the truck is raised up this incline with the end door closed, and this is not opened until the curved tipping portion of the track is reached. In this particular case the coal is discharged into an elevated receptacle. It has been found that coal trucks can be raised at an angle of 30° with the greatest safety, and no shifting of the coal takes place at this incline, neither is there any additional pressure against the end door. The expenditure of power is .7 kilowatt per 10 tons of coal handled, so that, inclusive of labour, the cost of handling 10 tons is a fraction over twopence, and when handling more than 7,000 double loads (of 20 tons each) per annum, the expenditure on the installation is justified; at 7,000 the total expense, including the capital account, is equal to that of hand labour.

An interesting installation on the same principle is shown in Figs. 844 and 845. An ore pocket holding 60 tons is here filled by the trucks, and such a tip almost answers the same purpose as a

Fig. 849. One of the Installations of the North German Lloyd Co. at the Harbour at Bremen.

hydraulic coal tip, but the initial cost is considerably less. The weight of the truck is balanced by a weight which is seen at the back of the structure. The capacity of this plant is twelve 20-ton trucks per hour, and a 68 H.P. motor manipulates the tip. Figs. 846, 847, and 848 show the winding gear which can be used as a capstan to draw the wagons near, and revolve the turntable as well as lift the load. The power consumption for a 20-ton truck at the rate of 150 tons per hour is 1.5 kilowatts. Such an installation becomes commercially economical when handling over 275 tons per day.

A further and most useful development of the Aumund system is a portable tip, which may be handled in the same manner as ordinary rolling stock; it may therefore form one of the units of a mineral train, and be used for unloading at the destination of the train. For this purpose the tip is mounted like a turntable upon a low carriage, and fitted



Figs. 850 and 851. Portable Turntable Tip driven by Motor from Electric Main.



Figs. 852 and 853. Portable Turntable Tip driven by Petrol Engine and Electric Motor.

with motors according to local circumstances, taking the power from existing mains, or fitted with a primary motor of the oil or petrol type coupled to a dynamo. Figs. 850 to 853 are diagrams of electrically driven tips of this description. Their use is precisely similar to those already described, with the exception that the turntable (driven by a separate motor) is used when the truck on the tip has been raised to an angle of 30° , and when the table has been turned to an angle of 90° with the line of rails, the end door is opened, and the lift completed to an angle of from 45° to 55° . When the truck has discharged its load the turntable is used again, continuing in the same direction for another 90° , so that the truck may now leave the tip at the opposite end to that at which it entered. If used in this way the whole mineral train can be unloaded truck by truck, and the empties reunited for the return journey. These tips are self-propelling, and can therefore be used in a variety of ways, even dispensing with the locomotive when the mineral train has

only a short distance to travel. The wheel base and the distribution of the load upon the permanent way does not exceed the usual limits, so that these tips can be used in the way described on all sidings where ordinary railway engines travel. Eight trucks of 10 or 20 tons can be tipped per hour. The lifting motor is of 25 H.P.,

whilst those manipulating the turntable and for self-propelling are of 8 H.P. each. The power consumed is .5 kilowatt per every 10 tons handled. One driver and two labourers are necessary, and the cost (pre war) of unloading by these tips in Germany was reckoned to be just under 1½d. for every 10 tons of coal handled. Such tips are economical if the amount handled annually exceeds 6,300 trucks of 20 tons; for quantities below this they are not more economical than hand labour.

Rotating Tips.—Where the material to be tipped is of a sticky nature, and particularly also where wagons with hinged end doors are not available, a method is resorted to by which the wagon can be turned upside down so that its contents must be completely discharged. Such a method has many points in its favour, but the appliances necessary are obviously more expensive

Fig. 854. Rotating Tip of Babcock & Wilcox in Initial Position.

The principal advantages are that all open mineral wagons of a given capacity, say 12, 15, or 20 tons, can be tipped whether fitted with end or side doors; the power required for this is small because there is practically no lifting action, the trucks being turned round their longitudinal axis and as near as possible in its centre of gravity, and it is next to impossible to injure the trucks, which always remain with all their wheels on the railtrack.

The Babcock & Wilcox electric rotary tippie for railway wagons is illustrated in Figs. 854 and 855, the former showing the truck in position ready to be tipped, while the latter represents the same in tipping position. The device consists of, essentially, a mild steel cylindrical cage carrying a short length of railtrack for the reception of the truck. This is run in and secured in position by locking screws and cross-bars. In the position depicted in Fig. 854, the railtrack of the tippie is in correct alignment with the permanent railtrack leading to and from the tippie. The wagon is secured in this position by a stop attached to the circular path of the cage. When the wagon is in place

the cross-bars binding the wagon to the rails are lowered by means of a hand wheel, operated through worm gear shafting and wire ropes, and the links, binding screws, etc., attached. Since initially the load in the truck partially compresses the wagon springs, the binding screws are applied with only a slight tension.

When the truck is thus secured in position the motor is started which operates the train of gears revolving the four cast-steel rollers, on which the steel cage rests, thus slowly revolving the latter by friction. This motion is continued until the wagon is tilted to any angle required for perfect delivery. When empty, the motor is reversed till the truck is back in its original position, the cage is then automatically stopped in alignment with the railtrack, and the empty wagon is pushed out by a full one to be unloaded next.

Fig. 853. Rotating Tip of Babcock & Wilcox in Unloading Position.

The tippie is strongly made of mild steel channels and plates, the rings being built up in segments. The longitudinal tie-beams are also of mild steel, and strongly connected to the rings at the junctions; only a 5 H.P. motor is required to tip a wagon holding 12 tons. Six wagons per hour can be dealt with when the device is fitted with hand-clamping gear, as described, provided they are handled to and from the tippler sufficiently quickly; but the capacity of the machine can be increased to twelve or even more trucks per hour by the application of mechanically operated clamping gear. These rotary tips are built in three sizes, dealing with trucks up to 12, 15, and 20 tons net capacity.

The Patent Revolving Coal Tip with Automatic Locking Gear, by Spencer & Co., Ltd., Melksham, is on the same fundamental principle. It is illustrated in the annexed drawing (Figs. 856, 857, and 858), in three elevations, one being a side view, and the two others end views in the initial and tipping positions of the wagon.

In this machine the cage is revolved by a shaft and pinions which gear into cast-

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Wagon Tipper,
king Gear.

20 25 30 Ft.

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steel toothed quadrants bolted to the revolving rings of the cage. The driving shaft is actuated by an electro-motor of $7\frac{1}{2}$ B.H.P. running at 750 revs. per minute through speed reduction gear.

The portion of the standard railtrack which runs from end to end of the cage is not secured thereto, but to a platform within; this platform is constructed of rolled steel sections and plates, and is supported on cast-steel rollers so that it can slide to one side.

As the cage commences to revolve, the platform, supporting a full wagon, moves slowly by gravity towards the side of the cage until the truck touches a matting fender which reaches the full length of one side of the cage and which is fixed thereto, so that projecting bolt-heads, straps, etc., can bed themselves, thus providing a uniformly distributed support for the wagon. The rate of this sliding movement of the platform with its full truck is governed by the rollers, which travel on a cast-iron path, as the cage revolves, till the wagon rests against the fender.

Simultaneously with this movement the steel clamping girders or bars, which are provided over the wagon, are allowed to drop automatically until they rest on top of it. Further rotation of the cage lifts the balance weights attached at one end to two steel wire ropes, which are reeved over sheaves located within the above mentioned clamping girders and have their other ends attached to the cage. The further rotation of the cage thus tightens the ropes and presses the clamping girders tightly upon the truck, the rotation lifting the weights off the ground. Under these conditions the cage is now rotated to a position in which the contents are unloaded, the truck being held rigidly in position.

On the direction of rotation of the driving shaft being reversed, the tipping platform commences to return to its original position, the balance weights thus coming to rest on the ground again, and as the cage further revolves, a lever strikes against a stop which causes the links, and with them the clamping girders, to rise, thus freeing the truck. At the same time the platform comes in contact with the roller path and slides slowly as the return movement proceeds, away from the side of the cage, eventually assuming its original position. When the railtrack is in register with the rest of the track, the empty wagon is then replaced by another full one. All these motions are automatic, and are synchronised with the rotation, either backward or forward, of the cage.

These tips are capable of emptying at least twelve standard trucks per hour, and in actual practice have done considerably more. They are made to deal with trucks of various sizes up to 40 tons. It should be mentioned that the cages of the machines described are only large enough for ordinary mineral trucks to pass through, and box trucks and locomotives cannot pass. To construct such machines of sufficient dimensions to permit a shunting engine to pass through, though possible, would increase the expense out of all proportion to the advantage accruing from such a course; and even in cases where such provision has been made, engines are hardly ever passed through. Bennis & Co., Ltd., who build a similar tip, divide the cylindrical cage horizontally in two halves, so that the upper portion can be removed for the purpose of permitting the passage of locomotives.

C—Tips which Unload Above the Level of Railway Lines, generally called Hoists.—The tips under this head are undoubtedly the most important of the three types, and are generally used in cases where a quay wall is not very high above the water level, or where large ocean-going steamers (the holds of which naturally extend above the level of the quay) have to be loaded with coal and other minerals.

It is obvious that in this third type of tips a great expenditure of power is necessary, because not only has the coal, plus the weight of the truck, to be lifted to a level considerably above the quay walls, but this has to be done at a relatively high speed.

The first mechanical coal tips of this description were lifted and tilted by hydraulic power. Such coal tips are still the most generally used, but electrically driven tips are beginning to be advocated. It may be said that the loading of coal ships has called into use a greater variety of hydraulic appliances than almost any other operation in the mechanical handling of material. The credit is due to Lord Armstrong, one of the pioneers of the hydraulic system, whose firm, Sir W. G. Armstrong, Whitworth, & Co., Ltd., have always

been well to the front in building hydraulic tips for loading vessels. It must be admitted that no fixed rule can be laid down as to the type of machinery to be employed in each individual case, as a great deal must depend upon position and local conditions. This applies not only to the various systems, but also to the various types of hydraulic machinery. Sometimes direct acting cylinders below the cradle are the most suitable, whilst in other cases hydraulic cylinders at the side of the structure manipulate the cradle by means of cables or chains, as the case may be.

The first coal tips of this description erected by Sir W. G. Armstrong, Whitworth, & Co., Ltd., consisted of a set of four at Cardiff, and another set of four at Newport. These were erected in the year 1858, and were followed in 1859 by the two tips at Swansea, and in 1861 by two at Briton Ferry. The latter were very similar to the Cardiff tips, which are of the type generally built by the Armstrong firm. Since those days, however, the power and height of the lift has been very considerably increased to suit vessels of greater tonnage, and so-called anti-breakage cranes have been added.

Figs. 859 and 860. Elevation of Cardiff Tip.

The Cardiff Tip.—The general type of the first Armstrong hydraulic tip and hoist is shown in elevation in Figs. 859 and 860, whilst Fig. 861 gives a plan of the same. Tips of similar construction are now being built with a lift of 40 ft. and over above the quay.

The cradle A which carries the wagon is raised by vertical hydraulic ram B, whilst the cradle itself is guided at its four corners by the framework, and the loaded wagon is raised to the level of the shoot E. The upper portion C of the cradle forms the tipping frame, and is pivoted at the front and tipped with the wagon upon it by means

of a second hydraulic cylinder *D* below the cradle, and attached to it as shown in Figs. 859 and 860. The cylinder oscillates on trunnions to follow the motion of the tipping frame, the hydraulic main being connected to the cylinder through one of the trunnions.

The whole apparatus can be controlled by a man standing on a side platform *F*, at the top of the structure, with the levers controlling the machinery close at hand. The raising and lowering of the shoot *E* for adjusting both height and inclination are automatically effected and are quite independent of hand labour. Two short arms project at each side of cradle *A* under the top end of the shoot. When the cradle is elevated the shoot is also carried up with it to any desired level, and is held in that position by weighted pawls, which fall into vertical racks secured at each side to the frame. By holding these pawls disengaged from the racks, the shoot may be lowered with the cradle to any level. The shoot is also secured by a safety chain on each side, which is fixed in each new position by a clip.

The two arms that lift the shoot are so balanced as to hang vertically and clear of it when out of use, but when required they are thrown into action by pulling a small chain. The end of the shoot can be raised or lowered in a similar manner, to give a greater or lesser fall, by means of two chains carried over pulleys at the top of the structure, and brought down the centre, one at each side, where they are secured to the frame by clips at the desired level. Whenever it is necessary to shift these chains they are pushed upon strong hooks fixed at the edge of the cradle, and then by lowering or raising the cradle the point of the shoot is raised or lowered as desired, and the chains are again fixed in a new position by the clips.

In some districts, South Wales for instance, where the coal is very friable, it is necessary to take special precautions for reducing the loss by breakage, which occurs in discharging the coal wagons into the ship's hold, and for this purpose the anti-breakage crane *N* has been introduced. For further development in this direction see description of the Penarth tips (page 592), in which full details of the Thomas Anti-Breakage Box¹ are given. The receptacle used in conjunction with this crane is the iron skip *P*, holding about 1 ton of coal. It is hopper-shaped, with a hinged flap door for discharging at the bottom and is suspended from an independent light jib crane *N*, fixed at one side of the tip frame, and having hydraulic lifting and turning motions. In commencing to load a ship, this bucket is filled from the shoot *E*, then lowered to the bottom of the hold, and there emptied by pulling up the bolt which secures the flap door. This process is repeated until a conical heap of coal is formed sufficiently high to

Fig. 861. Plan of Cardiff Tip.

¹ Other anti-breakage appliances are described and illustrated in the chapter, "Loading Coal into Ships otherwise than by Tips" (pages 633 and following).

reach nearly to the hatchway, after which the shoot is allowed to discharge freely without the use of the bucket and delivers close down upon the heap, a vertical drop being thereby prevented. The point of the shoot is somewhat contracted to check the speed of the coal down the incline. At this point the discharging sometimes requires a little assistance by hand, and is thus kept under control whilst the bucket is being filled. The whole process is effected much quicker than it takes to describe it, the discharge of the bucket in the ship's hold being self-acting, as the bolt which holds the flap door is fastened to a chain which is fixed to some portion of the rigging or deck, and thus the door is automatically released as soon as the bucket has reached the point of discharge. This anti-breakage crane may also be used with advantage for discharging ballast, as well as for filling into wagons the small coal that passes through a screen sometimes fixed in the shoots.

Figs. 862 and 863. Armstrong-Whitworth Tip fitted with "Burntisland" Anti-Breakage Box.

The latest tips of Sir W. G. Armstrong, Whitworth, & Co. are fitted with "Burntisland" anti-breakage boxes (see Figs. 862 and 863), so named from being first fitted on one of the hoists of the North British Railway Co. at Burntisland Dock. The appliance consists of a box fitted with side doors and a tripping ring, which automatically opens the box at any predetermined level when it is lowered.

Notwithstanding all these precautions, the proportion of dust found in the coal when the ships are discharged at the end of the voyage is generally very great. This breakage is undoubtedly partly due to want of care in trimming the coal in the ship's hold.

Hydraulic Tips at the Barry Docks.—Another hydraulic tip with a direct acting ram is illustrated in Figs. 864 and 865. It is the design of Sir John Wolfe Barry, and was erected by Sir W. G. Armstrong, Whitworth, & Co., Ltd., at the Barry Docks. This hydraulic coal tip consists of a substantial wrought iron framework supporting the shoot for conveying the coal into the hold of the vessel, and at the same time

serving as carrying guides for the lifting cradle on which the coal wagon is raised to the level necessary for discharging into the shoot.

The cradle itself is manipulated by two direct acting cylinders and rams (having a lift of 37 ft.), placed below the cradle as shown in Fig. 864. One of these rams is so proportioned as to balance nearly the whole weight of the cradle, and is in constant communication with the hydraulic main. The action of this ram is somewhat similar to that of a balance weight. The water which is forced into the cylinder during the lifting of the cradle is returned to the main during the lowering.

The function of the second ram is to lift the load and the unbalanced portion of the cradle. There is a third ram working in an oscillating cylinder attached to the rear of the cradle for tipping its upper portion, which is pivoted at the water side, and by which the discharge of the coal through the end

Fig. 864. Hydraulic Tip at Barry Docks (Side View).

door is effected. The water pressure for this tipping cylinder is taken from the main lifting ram, the action being similar to that of the preceding tip, and a load of 19 tons can be lifted and tipped. The tips were originally fitted with anti-breakage shoots to reduce the breakage of coal while passing down the shoot, but these were some time ago replaced by ordinary shoots fitted with a single door at the point of discharge for controlling the flow of the coal.

The adjustment of the shoot at the proper level and the housing of it when out of use is effected by the cradle itself, the front of which carries levers for taking the weight off the heel of the shoot in raising or lowering it. In the same way the delivery end of the shoot can be raised or lowered by chains, which can be connected to the cradle when necessary. On one side of the framing is a hydraulic anti-breakage crane, with a box of 3 tons' capacity, similar to the crane previously described. The whole manipulation of the tip is effected by hydraulic cylinders in the usual way, and all machinery is adjustable to suit any conditions. The hoist and crane valves are all operated by a man standing in an elevated cabin on one side of the hoist (see Fig. 865).

The tips illustrated in Figs. 866 and 867¹ are by the same designers and makers, and for the same docks. The principal difference between these tips and the one last described is that no part of the machinery is below the quay level. The two lifting cylinders below the cradle in the previous tip are replaced in the present case by four direct acting cylinders, contained in box girders which also form the four guides for the cradle. The lift in these tips is the same, viz., 37 ft., and the guides extend some distance above the top of the framing. The anti-breakage crane is for a load of 2 tons, and is in other respects similar to the last described. The tips are so arranged that they can at any future time

Fig. 865. Hydraulic Tip at Barry Docks (End View).

be converted into movable hoists should this be desirable.

² There are now thirty tips at the Barry Docks, all hydraulically driven, and 4,000 H.P. are stored up in the accumulators for use at any moment. This is an actual storage of foot-pounds always at disposal and ready, and at no more cost than the original outlay and the occasional addition of a few more gallons.

As to the volume of work done, this is more or less a traffic problem. When ships come in on one tide and want to go out on the next, as much as 4,000 tons of coal have been shifted in six and a half hours.

¹ From *Engineering*, 22nd March 1896.

² Remarks made by Colonel F. W. Tannett-Walker during a discussion on a paper read before the Institution of Mechanical Engineers, 20th January and 17th February 1911.



Fig. 806.

Fig. 806. Side View of Hydraulic Tip at Barry Docks.

Coal Tips at Newport.—A couple of tips, again similar to the last, have since been erected at the Alexandra Dock, Newport, Mon. They have, however, a lift of 3 ft more than the previous one, or 40 ft. in all, and their capacity is about 300 tons of coal



Fig. 867. End View of Hydraulic Tip at Barry Docks.

per hour. For working the wagons to and from the tip, Armstrong's capstans of 1 ton hauling power are used.

Movable Tip at Cardiff.—This was built by Sir W. G. Armstrong, Whitworth, & Co., Ltd., and is similar to the tips previously described. The capacity is 19 tons, whilst the

lift of the cradle is 31 ft. This tip is very like one of those at Rotterdam, with the exception that the lifting machinery, which consists of a ram and cylinder with multiplying sheaves, is placed on the back of the framing. It is mounted on wheels, which allow it to be moved to and fro on the quay to reach the hatchways of vessels, there being on the

Fig. 808. Movable Tip at Cardiff.

quay a number of lines, opposite to any one of which the hoist can be placed; these lines radiate from turntables communicating with the full and empty railroads. These tips are most serviceable, as they enable two hoists to work into the same vessel, which, owing to the constantly varying position of the hatchways, two fixed hoists would very rarely be capable of doing. Fig. 868 illustrates this tip.

Coal Tips at Penarth Docks.—One of the four movable tips at Penarth Docks is illustrated in Figs. 869 and 870. These are placed on the north side of Penarth Dock Basin, and resemble those at Cardiff, but have a total height of 96 ft. ; they are capable of being moved by means of hydraulic hauling engines. Every part of the machinery

Figs. 869 and 870. Movable Tip at Penarth Docks.

of this hydraulic tip, the cradle, tipping, control of the shoots, and the movement and working of the anti breakage cranes and boxes, is under the control of one man in the high cabin on the east side of the tip. All the machinery, which has to work under pressure, has been tested to carry a pressure of not less than 2,000 lb. per square inch, and the working pressure is 750 lb. per square inch. Each tip was constructed to fulfil the following requirements:—

A loaded wagon having been placed upon the cradle, to lift it 45 ft. above the quay, tip the contents of the wagon into the shoot, return the wagon to the quay level, and run it off the cradle within thirty seconds—and this can be accomplished. The cradle is lifted from the ground level to any height up to 45 ft. by means of four direct acting hydraulic rams, two on either side of the cradle. These are as follows :—

Two small rams, one on each side, are in constant communication with the high-pressure mains, and act as counterbalances for the weight of the cradle itself. The large ram and cylinder on each side of the cradle are intended to deal with the weight of the wagon with load, and of that portion of the cradle not balanced by the small rams. They are capable of lifting the cradle with a fully loaded 10-ton wagon upon it at the rate of 180 ft. per minute.

The platform or cradle upon which the trucks are raised is shown in the front view in the illustration at its lowest position, whilst in the side view it is shown raised and tipped. The A-shaped sides of the cradle *a* are connected at the top by a girder *b*, this is again connected by the rods *cc* to a second girder which slides in the guides *dd*, which extend above the actual framework of the structure. The second girder is manipulated by the four hydraulic rams already mentioned.

The appliances for working the cradle are fitted with automatic stops *b*₁, so that, the height at which the tip shoot is required to work having once been fixed, the cradle when started ascends to the tipping point, where it is automatically stopped, so that the attendant has only to start the cradle for lifting, when he is free to handle the lever for tipping without further attention to the lifting of the cradle. Again, in lowering, as soon as the wagon has been tipped, the top man has only to open the release valve and the cradle descends, and is automatically stopped as it reaches the bottom.

Each tip is fitted with two anti-breakage cranes and Thomas's patent anti-breakage boxes (see Figs. 871 and 872), and is capable of "boxing" (as it is termed) as rapidly as the coal can be delivered into the shoot. The small anti-breakage crane is also fitted with slewing gear for conveying coal screenings ashore.

The tip shoots *h* are 24 ft. long, but can be lengthened up to 30 ft., and in order that the coal may slide gently out of the shoots to avoid breakage, they can be rapidly adjusted by means of ropes *gg* and *f*.

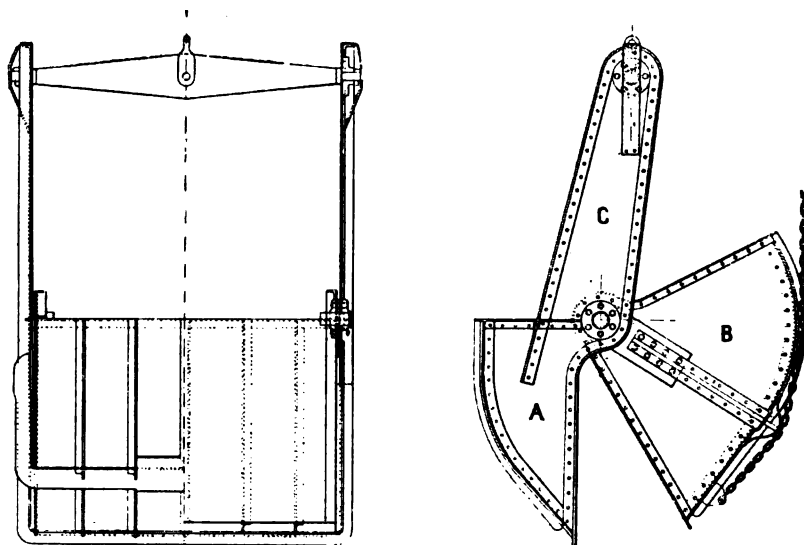
The tips are quite large enough to hold a 10-ton wagon of coal, the largest size used in the district. The shoots are fitted with double wings for assisting in the trimming of the coal and also in the boxing, and they are further made to radiate 5 ft. in either direction from the centre line of the tip, to assist in minimising the trimming. In connection with each tip is a traversing turntable platform, and two turntables, one for the empty and the other for the full trucks. These platforms are also fitted with hydraulic capstans of a capacity of 2 tons' pull, which can be moved to suit the position of the tips.

The whole of the hydraulic power required is brought to these tips by two mains, each 8 in. in diameter, so arranged that in the case of the failure of either one or the other, it is possible, by an arrangement of stop valves and branches connecting them together at intervals, to cut out any section of these mains and so turn the water past the defective section. The return water is carried back by a 12-in. main to the hydraulic engines. Two large accumulators are fed from these mains; one at the eastern end of the tips, the other at the engine-house. The water is pumped by three pairs of compound "tandem" engines, collectively capable of delivering 1,440 gals. of water at a pressure of 750 lb. per square inch per minute.

The sidings are so arranged in connection with these tips as to facilitate the mixing of coal and ensure rapid dispatch. Provision is made by which all wagons are weighed when coming in and reweighed when going out, the exact weight of the coal thus being ascertained, no matter what the tare of the wagons may be. The sidings are so laid out that a full train can be put upon either. They will together hold a cargo for a steamer of 2,500 tons, and are so constructed, with a slight rising gradient to the centre, and a falling gradient thence to the tip, that the men engaged at the tips manipulate the whole train load and work it down without the assistance of locomotives.

The capacity of these tips as regards dispatch may be gathered from the following data:—

On 23rd May 1901 the S.S. "Gatesgarth" arrived in the dock at 8.10 on the morning tide, and immediately proceeded to the four-tip berth. After bunkering with one tip, she commenced to take in her cargo at 9.15 A.M., finished at 11.50 A.M., and



Figs. 871 and 872. Thomas's Anti-Breakage Box.

sailed on the same tide, having taken on board a cargo of 2,333 tons in two hours and thirty-five minutes. On 26th July 1901 the S.S. "Bangarth" arrived in the dock at 11.45, and at 11.55 all four tips were at work, and she was charged with 2,154 tons of coal by 1.55, *i.e.*, in two hours.

Thomas's Anti-Breakage Box.—This is the invention of Mr S. Thomas, dock superintendent at Penarth, and is illustrated in Figs. 871 and 872. It has a capacity of $2\frac{1}{4}$ tons, the main object of its design being non-breakage of coal when working rapidly. It is in two sections, A and B, which hang vertically from the same bridle C, and are hinged together near the top of the box, being so arranged that when the box is empty the act of lifting it by a rope causes it to close automatically, and it is closed while being loaded under the shoot of the tip. An auxiliary rope is attached by an eye-bolt and chain to the heavier half of the box, and passes up to the end of the jib of the crane which works the box, passing thence over a sheave on the outside of the jib, while the end is brought back down to the deck of the ship, where it is fastened at any desired length.

Upon the anti-breakage box being filled with coal, it is lowered into the hold through the descent of the main lifting rope of the box; the auxiliary rope tightens and the box opens as shown. As soon as the contents are discharged and the main rope is lifted to bring the box back up to the shoot again, the auxiliary rope becomes slack and the box automatically closes, and is then ready for loading again.

The box is made of steel plates, angle irons, and T irons. It may be added that it is a great improvement upon the former system of anti-breakage boxes used at Cardiff. The old style had a bolt for securing the door, but when working rapidly it frequently happened that this bolt did not drop into the right hole, consequently the door would open at the wrong moment and the coal was liable to be dropped too far and broken.

The Penarth installation was built to the design of Mr T. H. Riches, M.I.C.E., chief engineer to the Taff Vale Railway Co., by Fielding & Platt, Ltd., of Gloucester, whilst the engines and hydraulic machinery were built by Tannett, Walker, & Co., of Leeds.

Fig. 873. Plan of Immingham Dock, showing Position of Coal Tips.

Coal Tips at Immingham Dock.¹—Probably the largest installation in this country for loading ships with cargo coal is that equipped by the Great Central Railway Co at Immingham (opened on the 22nd July 1912) on the estuary of the Humber, where this company spent nearly 2½ millions sterling on the dock.

The coal shipped from this harbour comes from the coal fields of South Yorkshire, Nottinghamshire, and Derbyshire. The equipment of the harbour includes seven large tips on the south bank of the dock. The tips are generally of the same type as the six large tips at Cardiff, but with an increased capacity of 300 tons each per hour. This enhanced capacity is chiefly due to the more perfect general arrangement of approaching the tips, in respect of the facility with which the full trucks move on to the tips and the empty ones move out of the way. The general disposition of the railway lines and the position of the tips will be seen from Fig. 873. Six of the tips *a* are stationary, whilst *a*¹ is movable on rails (those at Cardiff are all six movable).

Whilst the capacity of the Cardiff tips is handicapped by the time lost in disposing of the empty trucks, at Immingham this loss is reduced to a minimum by having special

¹ For full description see *Engineering*, 14th and 21st June 1912.

sidings for the full as well as for the empty trucks, and by the way in which they run to and from the tips by the incline of the rails. The rails for the full trucks are on the ground level, whilst those for the empties are raised on staiths whereby they are entirely out of each other's way, and the use of turntables is dispensed with. The rails *c* approaching the tips can accommodate 2,560 full trucks, and the network of lines *e* supplying the former can accommodate an additional 9,120 trucks, so that nearly 11,700 full trucks with 117,000 tons of coal can be in waiting for the seven tips. When the loading is in full swing the seven tips can dispose of 50,000 tons per day into the ships. In addition to this there is a further tip *b* in the Humber for bunkering steamers without having to enter the dock; this is likewise served by separate lines of rails *d* in a similar manner raised on staiths. Finally there is the movable tip *a*¹ in a line with the other six stationary ones. This portable tip is served by an elevated line of rails of about 100 yds. in length, which is about equal to the travel of the tip and parallel with it.

The tips themselves are on the same principle as those at Cardiff and most other British ports, hydraulically driven; so it appears that the efforts made in some quarters to introduce electrically driven tips have failed to demonstrate their superiority, or this installation would probably not have been driven hydraulically. In general appearance these tips are so similar to a number of those already illustrated, that it would be superfluous to give illustrations of them.

The hydraulic system, which had its birth in this country, is undoubtedly generally preferred for manipulating this class of machinery, in spite of the efforts made on the Continent to drive such appliances electrically, and surprise was expressed there that such a modern installation as that of Immingham should be hydraulically driven. The prejudice against this system on the Continent has probably in part to be accounted for by the colder climate there, and the difficulty of preventing the freezing of the mains, etc. Apart from climatic influences the balance of advantages seems in favour of the hydraulic over the electrically driven tip. In the first instance hydraulic tips are less expensive in first cost, they are far less complicated and can be attended by unskilled men, which would be hazardous with electricity. With regard to the question of economy, it may appear at a casual glance that electric motive power can be more economically adjusted to the work, but if we take into account that the load of the tip is in most cases the same, the lack of accommodation in hydraulic power to varying loads does not enter into the calculation, and when the load varies, as on the Clyde and in other docks, multiple rams are now employed, so that on account of economy no advantage can be claimed for electricity, provided always that a sufficient number of hydraulic appliances are to be served from the same mains to warrant the installation of an up-to-date plant.

In order to meet further developments in the size of the ships of the future, the new hoists have been provided with a greater lift, and in all probability, with one exception, these tips are the highest yet constructed, the range being 70 ft. above the rail level, except in one in which it is only 56 ft. The wagon at this height is tipped at an angle of 45°. The tips deal with end-tip or bottom-door wagons of a gross weight of 30 tons, the dimensions of the wagons provided for being 25 ft. long over the buffers, 8 ft. 3 in. wide, and 8 ft. 8 in. high. The full wagons are drawn on to the cradle at the quay level and empties are run off on an overhead viaduct. There has also been a general advance in the speed at which these tips operate, and 180 ft. per minute is the rate that has been adopted with a pressure of 300 lb. per square inch on the accumulators at the power house.

The hoists are double-powered, being capable of dealing with wagons of either 30 or 20 tons' weight, including contents.

The framing is constructed of steel plates and angles, braced vertically and horizontally, and secured to the concrete foundations by eight wrought-iron bolts and nuts. The hoist-cradle is similarly constructed. The floor is timbered on each side of the rails. The tipping frame, which is also of steel, is hinged at the front end of the cradle, and is fitted with rails having turned-up ends, while to the rear is a cross-beam, to which the tipping ropes can be attached. The two hoisting ropes are $7\frac{1}{2}$ in. in circumference, and have a breaking strength of about 195 tons. The tipping ropes are of $4\frac{1}{2}$ in. circumference, with a breaking strength of 72 tons. The cradle guides are formed of steel angle-bars bolted to timbers, which are carried on the sides of the framing. On the under side of the frame is a hopper, built up of steel plates and angles, for dealing with hopper wagons, an automatic tumbling apron being fitted to bridge over the space between the lower edge of the hopper and the heel end of the main shoot.

The lifting machinery consists of three hydraulic cylinders bolted to steel girders, and secured vertically to the side of the framing. The plungers in the cylinders are of cast iron, and work downward through a gland acting on the cross-head. This is fitted with guides, one on each side, working on wrought-iron guide bars, each of which is carried at three points by brackets fixed on the girders on the hoist cradle. The cross-head is fitted with sheaves for taking the tipping ropes, as well as the multiplying sheaves for the lifting ropes, the ratio being 2:1. Conveyance sheaves are also fitted on the frame. One of the cylinders is arranged to be in constant communication with the accumulator, to partially balance the weight of the cradle and minimise the amount of pressure water used. When the maximum load of 30 tons is being lifted, all three cylinders are in use; but for raising 20 tons two cylinders suffice.

The hydraulic cylinder for tipping the cradle is placed over the lifting cylinders. The multiplying sheaves fitted in this case are in the ratio of 2:1. The arrangement of the lifting and tipping ropes is such that the tipping-frame can be tipped at any point of the vertical range of the cradle.

The shoot, which is of steel plates and angles, is fitted with hinged doors at the nose end, adjustable by chains to regulate the flow of coal. The outer end is raised or lowered by steel wire ropes, each $4\frac{1}{2}$ in. in circumference, and having a breaking strain of 80 tons. The shoot projects 25 ft. from the face of the framing when at the usual angle for working. The maximum height of the under side of the nose end is 56 ft. for five of the hoists and 42 ft. for one hoist above the quay level when the shoot is at the usual angle for shipping coal. A lengthening piece (6 ft. long) is arranged for, and slides under the shoot, being adjustable through a worm and a rack by hand gear on the cradle.

The working valves for the lifting and tipping machinery are of the balanced mitre type, having cast-iron casings with gun-metal spindles and seats. The valves are placed at the bottom of the framing, and are operated from the working cabin placed on the framing of the hoist. The valves in connection with the hydraulic engine for operating the shoot are located in the same place. There is also, adjustable from the working cabin, the automatic cut-off gear fitted on the lifting motion to bring the cradle to rest at any predetermined height. Stops are fitted on the rail level at the entrance to the hoist, and these are actuated automatically through levers and counterweights by the rise and fall of the cradle, the arrangement being such that the stops come into action, and prevent the wagons running into the hopper well when the cradle is raised. The hoisting and tipping machinery is, of course, encased in corrugated steel sheeting, fixed on steel frames.

The whole of the pipes—pressure and return water—are solid drawn steel tubes of the Mannesmann type.

At this dock eight tips, twenty-five cranes, as well as the dock gates, are manipulated by hydraulic plant (see Fig. 873) consisting of four double acting pumps, each of 600 H.P.,

Fig. 874. Side View of Coal Tip at Goole Docks.

with a capacity of 40 cub. ft. of water at a pressure of 815 lb. per square inch, with the necessary accumulators.

The seven tips in the inner dock were built by Sir W. G. Armstrong, Whitworth, & Co., and the one outside the dock by Head, Wrightson, & Co., Ltd.

Coal Tips at the Goole Docks.—These unique tips are illustrated by two photographic views, Figs. 874 and 875, and also by a sectional diagram, Fig. 876, although,

strictly speaking, they do not come under this heading, as they do not deal with railway trucks, but tip barges which contain coal. These compartment barges (which are each 13 ft. by 30 ft. by 6 ft. 6 in. deep) are brought down the Aire and Calder navigation. The boats pass along the canal in long strings, articulated together, and on reaching the dock they are floated, one at a time, on to the submerged cradle of one of the coal hoists.



Fig. 875. Front View of Tip at Goole Docks.

The cradle is then lifted till the barge is clear of the water, when clips are made fast to the rear of the barge, securing it to the cradle. The lifting is then continued until the barge reaches a height of 35 ft., when it is turned over sideways and deposits the coal into a shoot by which it is conveyed to the hold of the vessel. The empty boat is then returned to a horizontal position, the cradle is lowered and the empty boat floated off. Each barge holds from 25 to 35 tons of coal. The lifting of the cradle is effected by direct acting hydraulic cylinders placed vertically above the cradle, pistons with piston

rods being connected to it. The tipping movement in the first tip was effected by rotary hydraulic engines and chains, but in the later tips it is effected by cylinder and ram with multiplying sheaves and chains. These tips were built by Sir W. G. Armstrong,

Fig. 876. Sectional Diagram of Tip at Goole Docks.

Whitworth, & Co., Ltd., the first being erected in the year 1863, the second in 1888, and the third in 1900.

Coal Tips at Rotterdam.—The port of Rotterdam, from which a large proportion of the coal from the Westphalian coal fields is shipped, had long experienced the

want of a simple and efficient coal tip. The traffic in coal for export as well as for navigation purposes had grown enormously. The annual tonnage, which did not amount to 50,000 tons in 1890, had in 1900 grown to nearly half a million tons.

The tip—which was the first to be erected on the Continent and which is illustrated in Figs. 877 and 878—was built more or less on the lines of the tips in use at English ports, and its construction was entrusted to Sir W. G. Armstrong, Whitworth, & Co., Ltd. It was erected in 1887 and did most satisfactory work. It was driven from the existing hydraulic mains at the harbour, which are under a working pressure of 900 lb. to the square inch, and was for trucks holding 10 tons of coal, and designed for a lift of 33 ft.

Shortly after the starting to work of this tip the increased traffic rendered it necessary

Figs. 877 and 878. First Hydraulic Tip at Rotterdam.

to double the capacity, and a second tip was ordered from the same firm, this time for trucks holding 15 tons and for a rise of 40 ft., the latter to be accomplished in thirty-six seconds. Fig. 879 is an illustration of this tip.

The first hydraulic tip at the port of Rotterdam is suitable for all four-wheeled trucks used on lines that terminate at or have connections with Rotterdam. The framework is principally constructed of rolled girders, but wood is also used. *P* represents the cradle or stage for the reception of the trucks to be discharged. It is suspended from four chains at *c* and *d*, and is actuated by the hydraulic rams *x*, *x'*, the former of which has a larger diameter, with four sheaves *h* and *l*, and works downward, whilst the latter, *x'*, is smaller, works upward, and is fitted with only two sheaves *g*. The chains which are connected to the stage *P*, at *c*, are guided over the sheaves *e*, *f*, *g*, *h* to the hydraulic cylinder, and are attached at point *x*. Other chains lead from *d* to *P* over the sheaves *i*, *k*, *l*.

When the stage is in its lowest position, and the hydraulic ram *x* is forced down,

the stage moves upwards, as all four chains are tightened equally through pulleys *k* and *l*. When the stage has reached the level of the discharge shoot, the water is shut off at *x* and turned on at *x'*, which has the effect of lifting the stage from point *c* by the chains passing over pulley *g*, and so tilting it to a slanting position, which discharges the truck. The stage is then levelled again, by allowing the water to escape out of *x'* and then out

Fig. 879. Second Hydraulic Tip at Rotterdam.

of *x*, so that it drops by its own gravity; it is operated from point *H*, but there is an automatic stopping gear at the highest and lowest position actuated by the rod *s*. The weight of the stage itself is balanced by the weight *Q*, which hangs on a chain, the two ends of which are attached to *A* and *B*, and pass over the sheaves *a*, *b*, *c*, *d*. *T T* are two points from which the discharge of the trucks can be observed, and helped by hand if necessary.

A small crane with skip *K* is also provided for lowering coal in smaller quantities



[To face page 003.

from the large shoot, as already mentioned, for preventing breakage of the coal. The chain is manipulated by the hydraulic cylinders *y*, and the sheaves *u* and *v*. It is further guided over pulleys *q*, *v*, *s*, *t*. For the side movement of the crane an additional hydraulic cylinder *z* is provided. The hydraulic pressure which works the tip is 750 lb. to the square inch, which is sufficient for ordinary trucks, but when trucks of 15 tons' capacity have to be tipped, the pressure can be increased to 900 lb. per square inch.

The two tips sufficed to cope with the traffic until about 1898, when they were working almost day and night, and it was decided to erect a third tip. As the hydraulic power supply of the harbour authorities was taxed to its utmost limits after the erection of the second tip, and as some trouble had been experienced caused by the frost, and breaking of the mains through sinkage of the ground, it was decided to drive the third coal tip by electricity.

The Electrically Driven Tip at the Harbour of Rotterdam¹ is the design of Mr H. A. van Ysselsteijn, engineer to the city authorities. Nagel & Kaemp, of Hamburg, constructed the tip, while the electrical plant was the work of Siemens & Halske, of Berlin. The order for the third tip was passed to the contractors in 1897, but owing to some unforeseen delay it was not started to work until the beginning of 1901. This electric coal tip is illustrated in Figs. 880, 881, and 882. The general dimensions are similar to those of the tip illustrated in Fig. 867, which was built by Sir W. G. Armstrong, Whitworth, & Co., Ltd., but the framework was made stronger. The special novelty in the design is this, that the winding gears controlling the different motions have been placed in a separate engine-house erected close to the tip, each movement having its own electro-motor. Another feature peculiar to this third Rotterdam tip is that the delivery shoot is so constructed that it can be extended if coal has to be shipped into vessels of extra wide beam. It is thus equally suitable for loading coal into ocean-going steamers or into vessels for river and canal traffic. The wagons are drawn to the tip by an electric capstan, and are pushed upon the cradle; after discharging, they are returned on another line of rails. The framework is, as has already been stated, similar to that of the Armstrong tips, but there are four uprights on each side of the cradle, the two centre ones of which also act as lateral guides for the up and down motion of the cradle. The four uprights on each side are stiffened by trussed girders, which are secured to a substantial foundation. The main uprights are girders of Γ section, and are composed of and riveted together with angle irons. The struts are made of channel section. The bases of the uprights are secured to cast-iron footplates, which in their turn are secured to the foundation. The arrangement of the winding gears for the different movements of the tip in a common engine-room has been adopted because it is held that the gears are thus under better control, and can be kept under the supervision of one man, whereas, if they were situated at the different points where their action was required, each individual winding gear would require its own compartment to protect it from the weather. It would also, under such conditions, be altogether impossible for one man to manipulate all these gears. The slewing gear for the anti-breakage crane has been erected in the cabin of the operator, as may be seen in the illustration. This is the only part of the machinery for operating any portion of the coal tip which is not situated in the engine-room. Although the winding gears have been erected in the engine-house, they are all under the complete control of the operator, who can stop or start any of them from his cabin at the top of the tip. The connection between the operator's cabin and the engine-house by means of levers would have been exceedingly complicated. All connections, therefore, are electrical, even the brakes on the winding machinery being

¹ Illustrations reprinted from *Zeitschrift des Vereines deutscher Ingenieure*.

thrown in and out of gear by small electric motors. The following six winding gears have been erected:—

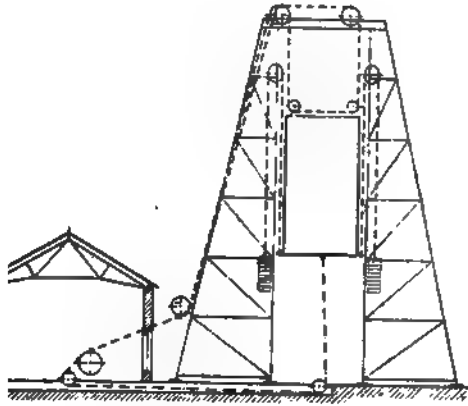
1. For lifting and lowering the cradle;
2. For tipping the cradle;
3. For raising or lowering the discharge shoot; and
4. For altering the incline of discharge shoot;
5. For lifting or lowering the anti-breakage skip;
6. For slewing the anti-breakage crane.

The electric driving gears have been very carefully constructed, and the wiring has been insulated to resist the damp climate at Rotterdam. A continuous current of 500 volts is used, and the lowering of the cranes is effected by means of electrical brakes.

Figs. 883, 884 and 885. Winch for Raising and Lowering the Cradle.

1. *Winch for Lifting and Lowering the Cradle.*—The weight of the cradle, including the heaviest full coal truck, is 50 tons, and this is raised at the rate of 1 ft. per second. The action is illustrated by Figs. 886 and 887, which also show the arrangement of the balance weights. A steel wire rope is used, both ends of which wind on and off the grooves of the winding gear (Figs. 883 to 885), so that there is always the same tension on either end of the rope. The electric motor driving this winding gear is of 130 H.P., runs at 370 revs. per minute, and is mounted on the same bed-plate as the winding gear. The drum has a diameter of 40 in., which is necessary as the wire rope has a diameter of $1\frac{5}{8}$ in. The gearing for reducing the speed from the motor to the winding drum consists of two countershafts and spur wheels. The gear wheels are of cast steel, except the pinion of the motor, which is of raw hide. The first of these countershafts is fitted with a brake at each end, which enables the operator to stop the load in free suspension, when the current is cut off. As soon as the cradle has

reached the top of the frame, the current is automatically cut off by an arrangement on the second countershaft. During the lowering of the cradle the weights on the band



Figs. 886 and 887. Diagrams showing Method of Raising and Lowering the Cradle.

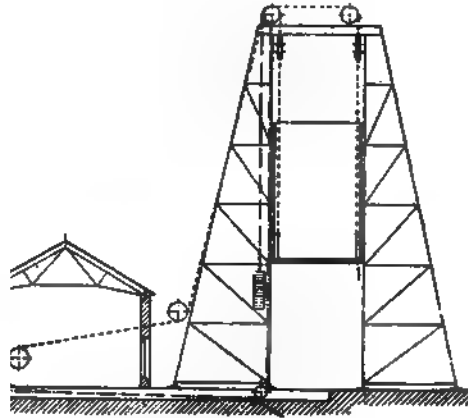
brakes are lifted by a small electro-motor. The gear of the brake is also fitted with a dashpot to ensure the brake action being smooth when thrown in or out of gear. The winding drum has, in addition to the grooves for the two rope ends, a third groove for a smaller rope for the purpose of pulling the cradle down should repairs be needed, or for

Figs. 888 to 890. Winch for Tipping the Cradle.

trial purposes, supposing the cradle should have to be lowered without a wagon on it. This rope is not usually on the drum, but is only put on in case of emergency, as the cradle being practically balanced, will not descend without an empty truck. All bearings

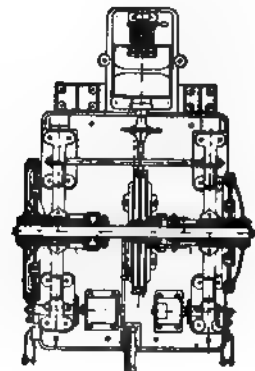
of the winding gears and guide pulleys are of the roller type, friction being thereby reduced to a minimum.

2. *The Winch for Tipping the Cradle.*—This is illustrated in Figs. 888 to 890. The tipping process is thus effected: The portion of the cradle which supports the coal



Figs. 891 and 892. Diagrams illustrating Tipping of the Cradle.

wagon is hinged by two trunnions on the water side, while two ropes at the back raise the movable part of the cradle for the purpose of tipping the contents of the truck. The diagrams, Figs. 891 and 892, show the connection of the ropes between the winch and



Figs. 893 to 896. Winch for Raising and Lowering the Discharge Shoot.

the tip. With this arrangement the winch may run idle during the raising or lowering of the cradle.

There is also a third groove on the drum of this winch, for the purpose of keeping the tipping ropes taut. This winch is very similar to the preceding one, but the electro-motor is of 60 H.P., running at 530 revs. per minute, and the tipping portion of the cradle can be raised to an angle of 50°. As soon as this incline has been reached the current is automatically cut off, and the weight of the empty truck and of the tipping portion of the cradle is sufficient to return the former to the level position, the speed being regulated by the brake. Just before the level position is reached the brake is pulled up tight. When lowering the cradle both the brakes of the hoisting and tipping gear are released; this is necessary as the winch has to run round idle again during the lowering of the cradle.

3 and 4. *Winch for Raising or Lowering the Discharge Shoot, and Winch for Altering the Incline of the Discharge Shoot.*—These are illustrated in Figs. 893 to 896. The apparatus is fitted with two independent sets of winding gear, which can be

Figs. 897 and 898. Diagrams showing Manipulation of Discharge Shoot.

alternately coupled to the electro-motor, thus only one of the two operations can be performed at a time. The reversing of the coupling is done by hand. One of the winding gears serves to raise or lower the shoot, and the other to alter the incline. The rope connection between the winch and the tip is shown in Figs. 897 and 898, from which it will be seen how the ropes operate the shoot. The dotted lines which indicate ropes are clearly marked; the rope indicated by dashes and crosses controls the incline of the shoot, whilst the rope indicated by dashes and dots raises and lowers the shoot itself. The movement of this winch is designedly rather slow, as an alteration either to the height of the shoot or to its incline is only very occasionally made.

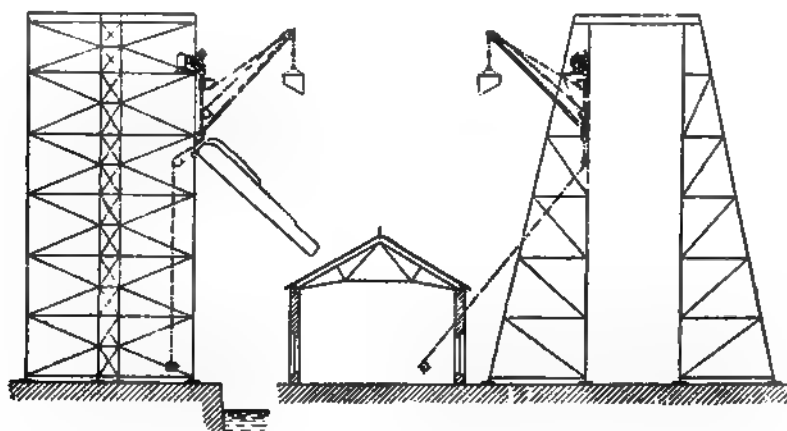
The raising and lowering of the shoot is at the rate of 3 in. per second, whilst the movement of the end of the shoot to alter its incline is performed at the rate of 4 in. per second. The motor which drives this double winch is of 17 H.P., and runs at 700 revs. per minute, and as the difference in speed is so great a worm and worm wheel are used here. One of the two winches is fitted with a band brake, the weight of which is lifted or lowered by a small electro-motor, similar to all the other brakes on the winches. On either side of the frame of the tip, against two of the main supports, are

fitted tooth racks into which the two pawls of the shoot are geared, to relieve the ropes of the tension until the shoot is to be raised or lowered again. No power is required to lower the shoot, as its own weight is always sufficient to turn the winch as soon as the brake has been released.

5. *Winch for Lifting or Lowering the Anti-Breakage Crane.*—This is illustrated

Figs. 899 and 900. Winch for the Anti-Breakage Crane.

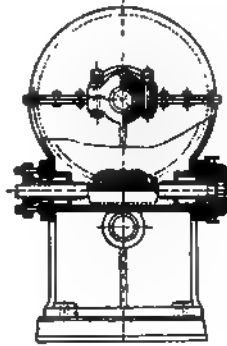
in Figs. 899 and 900. The crane itself is fitted to the frame of the tip in the usual manner, and the winch will lift the weight on the crane at the rate of 2 ft. per second. The connection between the winch and anti-breakage crane, by means of wire ropes, may be seen from Figs. 902 and 903, which explain themselves. The winch is driven by an 18 H.P. electro-motor, which runs at a speed of 630 revs. per minute, and the brake is similar to those previously described.



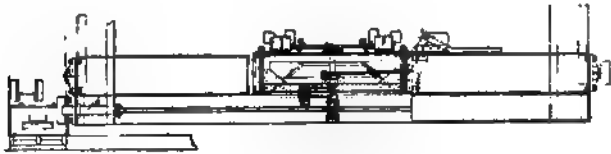
Figs. 902 and 903. Rope Connection between Winch and Crane.

6. *Winch for Slewing the Anti-Breakage Crane.*—This is illustrated in Figs. 904 and 905. The motor is connected to the slewing gear by worm and worm wheel, and a pair of spur wheels. The whole apparatus is so small and is so seldom used that the operator's cabin was undoubtedly the most suitable place for it. The motor is of 4 H.P., making 1,000 revs. per minute.

The Cradle.—This is of substantial construction, and is fitted with rollers which run against the guides of the framework of the tip. The sides are A-shaped, and there is a connecting piece at the top end which joins the two together. On the water side are two stands, accessible by steps, on which an attendant can take up his position. The tipping portion is built within the floor of the cradle, and is just wide enough for the two main girders—which are connected with each other by a framework of angle iron—to carry the rails upon which the truck stands. A strong girder at the end extends across the two longitudinal girders, which run the full width of the cradle, and the ends of this girder are provided with attachments, to which the tipping cables are connected. The rails on the tipping portion of the cradle are level for about three-quarters of their length, but are slightly bent upwards for the last quarter, thus bringing the truck to a standstill when it is pushed on the cradle. As the truck is pushed into position two automatic catches *aa* are forced



Figs. 904 and 905. Winch for Turning Anti-Breakage Crane.



Figs. 906 and 907. Details of Working Parts of Cradle in Plan and Elevation.

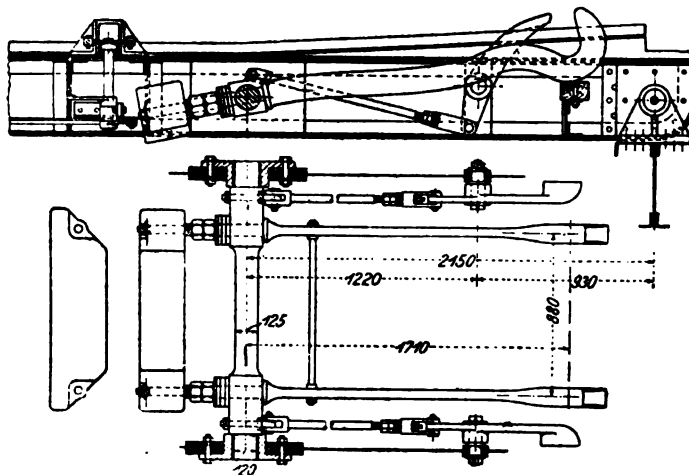
forward and prevent it from running backward. This is shown in illustration, Figs. 906 and 907, which gives the details of the working parts of the cradle in plan and elevation. Coupled with the two catches *aa* are two further catches *bb* which secure the cradle in its position when empty. These are now withdrawn in order that the cradle may ascend. To make the truck still more secure, the coupling chain at the end of the truck is attached to the cradle itself. This arrangement allows the truck to advance to its most forward position. As soon as the tipping process begins the truck rolls forward into this extreme position, and in doing so, it automatically secures its front axle by two substantial hooks, which are

pressed upward. The action will be clearly understood from Figs. 908 and 909, which represent the hooks which fit the front axle of the truck. They are coupled together

and are fitted with a balance weight; the levers at the sides are pressed down by the front wheels of the truck, and cause the two hooks to rise. The method adopted in this tip is identical with that of the original Armstrong tip. The cradle is balanced by counterweights which move up and down within the framework of the tip, and the tipping portion itself is balanced in a similar manner. Provision is also made for catching the cradle automatically should one of the ropes break.

The Discharge Shoot.—This shoot extends from the tip to about the middle of an average sized ship. The upper or feeding end is 12 ft. wide, but the shoot tapers at the tail end to 6 ft. 6 in. To this narrow end a lengthening piece is attached for extending the shoot, so that it can reach to the middle of the largest steamers. This piece is attached to a central girder beneath the shoot, and as it is mounted on rollers it can be pushed backwards and forwards as required by means of a worm and worm wheel. The extension is principally used for loading offside bunkers.

Figs. 910 to 912 give illustrations in plan and elevation as well as a cross section of



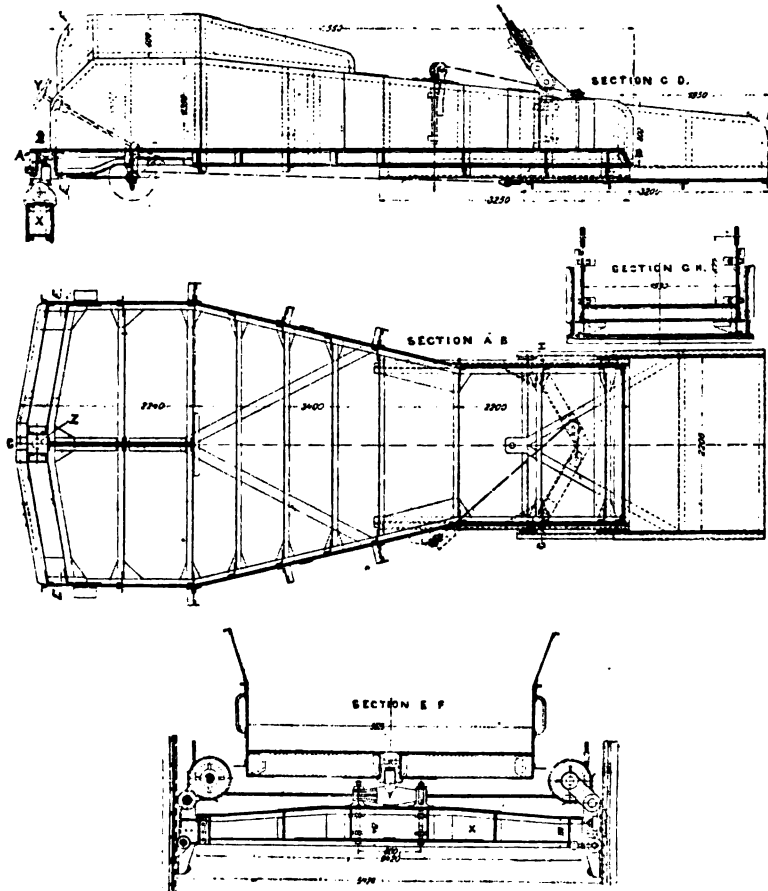
Figs. 908 and 909. Device for Fixing Railway Truck to Cradle.

(The dimensions are in millimetres.)

the shoot. The whole of the shoot is movable sideways round a steel pin *z*, which is secured in position by cross girder *x*, held by cables and pawls as has already been described, and both the steel pin *z* and cross girder *x* can be seen in the diagrams.

Manipulation of the Tip.—As already mentioned, the winches, with the exception of one, are placed in the engine-house, but are all operated from the cabin at the top of the tip, from which point the attendant can have all movements under his observation. The electrical starting and stopping gears are arranged on two floors of the cabin, which are illustrated in Figs. 913 to 915, and shows a section through the cabin, with plans of the upper and lower floors. On the upper floor will be found the starting gears for the lifting and tipping winches, and also for operating the discharge shoot, whilst on the lower floor is the starting gear for the anti-breakage crane, as well as the turning movement for the same. The stopping and starting gears for lifting and tipping are marked *A* and *B*. These are situated behind the manipulator, who faces the levers *A*¹ and *B*¹ from which the gear is operated. *C* is the starting gear for raising and lowering the discharge shoot; *D* is the trap door leading to the lower floor; *E*, on the lower floor, is the turning gear for the anti-breakage crane; whilst *F* is for raising and lowering the same; *G* being the

space for the counterweight. The ordinary position of the attendant is between A^1 and B^1 , and with his right hand he manipulates the raising and lowering of the cradle, whilst with his left hand he controls the tipping operation. With the backward movement of the lever the load is raised, whilst with the forward movement it is lowered. There is a safety appliance which prevents the tipping lever from moving during the raising and lowering of the cradle, and vice versa. The normal position of the levers is in the centre of the index, and as soon as one of the levers is moved in either direction, the other lever is



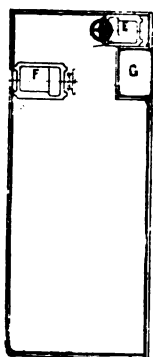
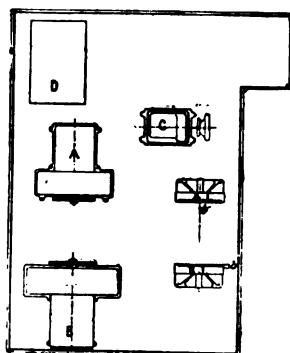
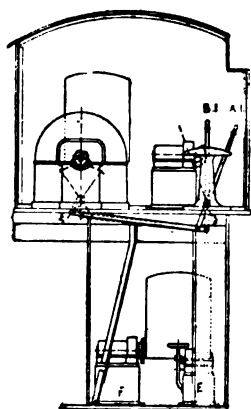
Figs. 910 to 912. Elevation, Plan, and Cross Section of Shoot.
(The dimensions are in millimetres.)

automatically locked until the former lever has again reached the central position. In addition to the operating levers, the cabin is fitted with the usual electrical instruments and cut-outs.

An electrically driven tip, similar to the foregoing, was installed in 1901 in the Dutch harbour of Emden ; it has a capacity of fifty trucks, together 225 tons, per hour.

At Rotterdam the full trucks approach the tip, and the empty ones leaving have to pass the same turntable; this causes delay and reduces the capacity considerably. Two turntables are used at Emden, which is a decided improvement.

The Electric Tips at the Rothesay Dock on the Clyde.¹—These tips are a vast improvement on those of the Continental type previously described.



Figs. 913 to 915. Section through Cabin, also Plans of Top and Bottom Floors.

The question was raised as to whether hydraulic or electric power should be employed by the Clyde Navigation Trustees, and in order to ascertain which of the two was more economical, two cranes were erected side by side in the Princess Dock, one being manipulated by electric and the other by hydraulic power. These were observed closely for a considerable time, and the result obtained was so favourable that no doubt was entertained as to the advantages of electricity for dealing with the ordinary class of machines such as cranes, capstans, etc. The installation of several large coal tips, however, rendered the problem one which had not hitherto been faced in this country. The mechanical difficulties in connection with such hoists had already been solved at Rotterdam and Emden, but the difficulty of dealing electrically with a large amount of horse power required in a very short period, together with the necessity of providing for rapid acceleration and retardation, and absolute control under all conditions, will be readily appreciated.

It was at this stage recognised that the problem had developed into one which could not be adequately dealt with by the mechanical engineering department, without expert electrical advice, and Mr Walter Dixon was appointed to collaborate with Mr Baxter, chief mechanical engineer to the Trustees, in the preparation of the scheme to embody the complete equipment of the dock.

The Power Station.—It is generally recognised that where a reliable supply is available it is desirable to take advantage of such supply and thus obviate a considerable capital expenditure. In many cases, however, an objection arises to this course, as the supply available is usually on the three-phase alternating current system, which, while it may be satisfactorily employed, is not so suitable for dock purposes as a direct current; so that if the best results are to be obtained, an appreciable portion of the capital which might otherwise have been saved by dispensing with steam-raising and generating plant, might have to be used for providing, converting, and transforming plant. In spite of such a supply being available at Rothesay Dock, it was deemed best to erect a generating station, as it was hoped that the electric supply would be produced at lower cost by a plant specially designed for the purpose.

The generating station, comprising boiler, engine, and condenser houses, suitable

¹ Abstract from a paper on the "Modern Electrical Dock Equipments," with special reference to electrically operated coal hoists, read on 20th January 1911 by Messrs Walter Dixon and G. H. Baxter before the Institution of Mechanical Engineers, with the Author's comments.

stores and offices, was erected in a convenient central position on the north quay of the inner basin. It is well known that the intermittent working of dock machinery causes excessive peak demands. If generating plant is designed of sufficient capacity to meet these demands it is necessarily large in proportion to the average load, and as a result, in addition to being expensive in first cost, it does not run under the most economical conditions. In order, therefore, to keep the plant within reasonable dimensions and to ensure economical running conditions, it has hitherto been the invariable practice to install a battery of accumulators with a reversible booster plant, in connection with dock installations. The possibility of adopting such a system, which has many good points, was carefully considered for adoption at the Rothesay Dock, but while it was recognised that it serves a very useful purpose under certain conditions of varying demands, such an installation would not adequately meet the more stringent requirements of the case involving as it did the special demands on the coal tips. It was therefore decided to investigate the possibilities of further developing the system, where excessive loads have to be dealt with, by coupling a prime mover, either electrically or steam driven, to a generator in conjunction with a flywheel. It was apparent that if these special coal hoist generators, and a further generator for supplying power for ordinary dock purposes, could be practically constructed in combination with a flywheel it would be very economical, and would dispense with the usual battery of accumulators, the flywheel taking care not only of the larger peaks due to the coal tip, but also of the smaller and more frequent demands for the other appliances.

The combination eventually designed consists of a high speed engine of the triple-expansion type, capable of developing about 450 B.H.P. as a normal load, when running at any speed between 320 and 375 revs. per minute. Direct-coupled to the crank-shaft of this engine is a continuous-current main generator, capable of producing current at a constant voltage irrespective of speed and load. This generator, which has a normal output of 340 E.H.P. with a considerable overload capacity, is used for supplying power to the ordinary dock appliances. The end of the main generator shaft remote from the engine is extended to take a special flexible coupling, by means of which it is connected to the flywheel shaft on which is mounted the flywheel and two coal hoist generators. In designing the plant it was intended that the storage of power in the flywheel should be such that with both tips working with full load and to their full lift, the average demand from the engine should not exceed its normal rated power. By trial it was ascertained that these conditions were fulfilled, and that, even with the main generator loaded to about 63 per cent. of its normal output in addition to the tips working as above, the demand only slightly exceeded the normal output of the engine with a drop in speed of the combination of about 20 per cent. The flywheel is entirely enclosed in a cast-iron case, the object of providing this being that, should the power required to maintain the flywheel and two hoist generators at normal speed prove excessive, the former could be run in a vacuum, but as the power required was only about 20 E.H.P., when running at the maximum speed of 375 revs. per minute, the installation of the necessary gear for producing the vacuum was considered quite unnecessary. Of course the above power is only consumed when the coal tips are in operation, and under ordinary working conditions considerable economy is effected by disconnecting the flywheel by means of the special coupling referred to above, when the engine and main generator run as an ordinary generating plant.

The Tips.—The two tips first erected, each of the high level and fixed type, are so arranged that the loaded wagons are run on the tipping platform at the quay level, raised to the required height and tipped, after which the empty wagon is lowered to the high

level inclined viaduct, leaving the hoist platform or cradle at a height of about 17 ft. from the ground and gravitating to the siding, the cradle then being lowered to the ground level to receive the on-coming loaded wagon.

Hoist No. 1 is fixed on the east quay of the outer basin, and No. 2 on the north quay of the inner basin, No. 1 being suitable for lifting to a height of 50 ft. and No. 2 to a height of 60 ft. Each hoist is capable of raising, tipping, and lowering wagons carrying 20 tons of coal, with a gross weight of 32 tons, as well as those of the ordinary type at present in use holding 6 tons and upwards.

It is always expedient to decide the working speeds of dock appliances in relation to the complete cycle of operations of which they form a part, but this is particularly so in the case of coal hoists, as so many operations are involved in addition to the actual hoisting of the load, that a high speed of hoisting, while causing a considerable increase in the first cost of the machinery and also in the power required for working, does not result in a corresponding high rate of coaling, unless it is possible to deal with the other operations—such as disposal of coal in the ship, getting into position of the loaded wagon, and the running off of the empty wagon—so expeditiously that advantage can be taken of a high hoisting speed.

After careful consideration of the cycle of operations necessary to ship the maximum quantity of coal, under the system of coaling generally in vogue at docks on the Clyde, where end-tipping wagons are used, it was decided to adopt a mean hoisting speed, allowing for acceleration and retardation, of about 100 ft. per minute with full load, corresponding to a time of thirty seconds for the full height of 50 ft.; this speed, with a full unbalanced load and a combined mechanical and electrical efficiency of 72 per cent., being equivalent to about 300 E.H.P. in the motor.

Perhaps the most difficult motion of a coal hoist to deal with electrically is the tipping, as this has to be accomplished very expeditiously through a comparatively short distance, usually a maximum of 45° ,¹ and with a degree of accuracy very difficult to attain under such varying conditions and loads. It is always necessary to accelerate quickly, and sometimes to stop suddenly and thus give an impetus to the material being shipped, so that it will leave the wagon without sticking. Frequently this motion has to be repeated through small angles of travel several times before the whole of the material leaves the wagon. To tip the full wagons to a maximum angle of 45° in six to nine seconds requires power almost identical with that for hoisting, so that the motors for the two motions are duplicates.

The design of the structural work and arrangement of shoot, jib cranes, and other auxiliary apparatus is on the usual lines, the essential difference being that all the gearing is at the top of the structure, which has been designed to carry this additional weight, and not, as at Rotterdam and Emden, in a separate building by the side of the hoist. As mentioned above, separate motors are employed for the hoisting and tipping motions. The hoisting motor drives, by means of an elastic coupling and also an ordinary jaw-coupling, a pinion which engages with a spur wheel upon the countershaft, this spur wheel and pinion running in a cast-iron casing. At each end of the countershaft a pinion is fixed which engages with the spur wheels firmly fixed to the hoisting drums, the drums being so arranged that the ropes go directly to the cradle without the intervention of guide pulleys. The whole of the gearing, with the exception of the motors, is erected

¹ It has been observed by Mr William H. Patchell that in tipping a full truck of large coal it could be done at a comparatively low angle, probably 38° , but in tipping small coal, particularly if it had been washed, there was some difficulty in emptying it out at 45° ; and if for any reason the tipping had to be interrupted and there was half or quarter of a truck still to tip, it had to be practically raked out.

upon a cast-iron bed-plate to obviate errors in erection, and both motors are mounted upon one base-plate, which is bolted to the gearing base-plate. For the purpose of taking up the slack of the tipping rope during the raising of the platform, a third drum, of barrel shape towards one end, is connected to one of the hoisting drums. The tipping motor is a duplicate of that for hoisting, and the gearing generally is similar, excepting that only one drum is employed.

In view of the heavy loads to be dealt with, and the precision with which the cage and tipping cradle have to be brought to a stop at any predetermined position, the brake gear is of great importance. The brakes for both hoisting and tipping are of the friction clinch type, the brake bands being kept tight during the hoisting, and the clinches revolving freely in the hoisting direction. By this means the load is held in suspension immediately power is disconnected from the motor. In lowering, the brake bands are released by electro-magnets in the usual way. Due to the fact that the hoisting and tipping motors are duplicates of each other, it has been possible to provide a simple arrangement by means of which either motor can work both motions in case of breakdown to the other, thus enabling coaling to be proceeded with and avoiding any serious delay in the departure of a vessel.

There is only one control lever, which works in a quadrant or frame, and by moving this lever in the various positions the attendant has control of the hoisting, tipping, and jib crane, the only other controller being a small one for controlling the slewing of the jib crane. Gearing is arranged in connection with this control-lever frame, which automatically renders it impossible for any of the motions to exceed their predetermined efforts, and it is also impossible for the attendant at starting to move the lever at such a rate as to accelerate at too great a speed and consequently throw an undue load upon the generating station. In fact, at all points of possible danger, the automatic adjustments come into operation, and prevent any damage from error of omission or commission on the part of the attendant. In actual working it has been found that the control is so perfect that the cradle can be brought to rest quite smoothly at any desired position, and in a similar manner the tipping platform can be quite smoothly stopped at any desired position. The wagons while on the hoist and when being run off are thus protected from the rough usage to which they are frequently subjected during coaling operations.

In Table 1 the specified cycle of operations is tabulated, from details obtained at the official trials. Comparing these with the results tabulated in Table 2, which were obtained in February 1909, after two years' working, it will be seen that the time required for coaling through the cycle of operations is considerably shorter.

Since the first two coal hoists were erected and set to work, two additional hoists have been installed, practically duplicates of the first two; for the result of some years' working did not suggest any modification or improvement for the further hoists, the only practical difference being that the two later hoists were for a higher lift.

Efficiency.—At the official trials in May 1907, which were taken when the hoists had done practically no coaling under actual working conditions, the following readings were taken upon hoist No. 2:—

Total unbalanced load	-	-	-	32 tons 0 cwt. 1 qr.
Height lifted	-	-	-	60 ft.
Time hoisting	-	-	-	36 seconds.
Speed of hoisting	-	-	-	100 ft. per minute.
H.P. due to load	-	-	-	217.3 load H.P.
Current	-	-	-	500 amperes.
Voltage	-	-	-	450 volts.
Electrical H.P.	-	-	-	301.6.

These readings show a combined efficiency of 72 per cent., which figure is within that guaranteed by the contractors.

During the coaling of a ship on 10th February 1909, particulars of which are tabulated in Table 3, several ampere and voltage diagrams were taken.

TABLE 1

Details of Specified Cycle of Operations.	Gross Weight.		
	Tons, 16½.	Tons, 18½.	Tons, 28½.
	Sec.	Sec.	Sec.
Securing wagon on cradle and raising to a height of 50 ft. - - -	33	33	33
Tipping loaded wagon - - -	7.5	7.5	9
Lowering platform with empty wagon to cradle chamber - - -	7.5	7.5	9
Lowering cradle with empty wagon to high level viaduct - - -	24	24	24
Uncoupling and running wagon off - -	14	14	14
Lowering empty cradle from high level viaduct to ground - - -	14	14	14
Total time per cycle - - -	100	100	103

TABLE 2

Details of Actual Cycle of Operations.	Gross Weight.		
	T. C. Q. 16 6 2	T. C. Q. 18 6 0	T. C. Q. 28 8 0
	Sec.	Sec.	Sec.
Securing wagon on cradle and raising to a height of 57 ft. - - -	30	30	31
Tipping loaded wagon - - -	8	8	9
Lowering platform with empty wagon to cradle chamber - - -	6	6	6
Lowering cradle with empty wagon to high level viaduct - - -	24	24	24
Uncoupling and running wagon off - -	8	8	8
Lowering empty cradle from high level viaduct to ground - - -	12	12	12
Total time per cycle - - -	88	88	90

The following *résumé* is from the diagrams taken:—

Gross load - - -	- 16 tons 17 cwt.
Speed of hoisting - - -	- 92.75 ft. per minute.
H. P. due to load - - -	- 106 load H. P.
Current - - -	- 225 amperes.
Voltage - - -	- 440 volts.
Electrical H. P. - - -	- 132.7.

These readings show a combined efficiency of 80 per cent. The instruments used for taking the electrical readings were fixed in the generating station, thus the readings include distribution losses.

TABLE 3

Number of Wagons Dealt With.	Total Time of Coaling.	Equivalent Number of Wagons per Hour.	Height of Lift.	Weights.			Tons of Coal per Hour.	Time per Cycle.	Total Units.	Units per Cycle.	Units per Hour.	Units per Ton.	Tons per Unit.
				Gross Weight.	Net Weight.	Average Weight of Coal per Wagon.							
30	M. S. 31 37	57	Ft. In. 27 10	T. Cwt. Qr. 416 10 2	T. Cwt. Qr. 252 14 0	T. Cwt. Qr. 8 8 1·9	479·5	Sec. 63·2	25	0·833	47·44	0·098	10·1

The result shows that the efficiency of the hoists had considerably improved during the two years' working, and, as it was obtained at half-load, further clearly demonstrates the high efficiency of electricity over wide ranges of working.

Working Cost.—The cost of the electrical energy, including coal, water, stores and oil, wages, repairs, etc., is ·89d. per unit. This cost is estimated as an average, with a consumption of approximately 560,000 units per annum. The capital charges increase this figure to about 2d. per unit.

The particulars obtainable for hydraulic power, variously estimated at from 2d. to 1s. 9d. per 1,000 gals. at a pressure of 750 lb., cannot obviously be on the common basis, but in any case the fact must be recognised that whereas the supply of electricity to any given quantity of work is a direct measure of work done, the supply of water in the case of hydraulics is always more than the quantity required, and therefore some of it is wasted; this waste may vary from 5 to 50 per cent. (what is here termed waste does not, in a modern installation, however, exactly apply, as such water is always returned to a second set of accumulators).

Two gals. of water per minute, at a pressure of 750 lb. per square inch, is reckoned equal to 1 H.P.

The conclusions to which Messrs Baxter and Dixon came were: Firstly—Electric and hydraulic systems are equally reliable. Secondly—The cost of working with electrical and hydraulic power is equal for full loads, but under variable and low load conditions electric power is cheaper. Thirdly—Electrical power has now the equivalent of a hydraulic accumulator. Fourthly—Electrical power can be applied to all dock appliances, and has greater flexibility than hydraulic power.

It must be mentioned here, with regard to the first conclusion, that we have only five or six years' experience with electrical tips, whilst with hydraulic ones we have, thanks to the genius of Lord Armstrong, an experience of over sixty years, and we know that some of the earliest tips, though perhaps not up to date, are still as serviceable as ever they were.

With regard to cost under the second conclusion, this was based on the cost of 9d. per 1,000 gals. of pressure water. This estimate is considered excessive by hydraulic experts, and it is asserted that hydraulic power can be produced at from 2d. to 3d. per 1,000 gals.

In addition it might here be mentioned that hydraulic coal hoists or tips have an advantage over electric hoists, as it is not necessary to employ wire ropes either for lifting, tipping, or balancing, the wire rope being often a source of anxiety to those in charge.

Working Results.—The coal and other material shipped by the two hoists during twelve months was 556,419 tons. The units consumed during this period totalled 80,164, and the number of wagons dealt with 70,604. During this period as many as 23 tons of coal per unit have been shipped, while, including all distribution losses and

also the power necessary for the working of all auxiliary apparatus on the hoist, including the jib crane, adjusting of shoot, and shoot point, etc., the current consumed over the whole period only averaged one unit per 6·94 tons of coal shipped. As emphasising the adverse conditions under which the hoists are at present working, it will be noted that 70,604 wagons were handled in shipping 556,419 tons of coal, or an average of only 7·88 tons of coal per wagon.

Referring again to the coaling of 10th February 1909 a note was taken of the speed of working under ordinary conditions, when thirty wagons were shipped into the vessel in thirty-one minutes thirty-seven seconds, which is at the rate of fifty-seven wagons per hour, the height lifted being 27 ft. 10 in., and the total weight of coal shipped 252 tons 14 cwt. Had the wagons been as large as the hoists are constructed for, the total quantity of coal shipped would have been at the rate of 1,140 tons per hour. As mentioned above, these results are tabulated in Table 3, and, in order to enable a comparison to be made with the results obtained at Newport, these results are adjusted in Table 4 to an assumed height of lift of 46 ft. From this table it will be noted that, while the average quantity of coal per lift given by Mr Macaulay was 11 tons 2 cwt., for Rothesay Dock it was only 8 tons 8 cwt. 1·9 qr., so that electric hoists with wagons containing a similar quantity of coal to those at Newport could have loaded an additional 117 tons, making a total of 477 tons 6 cwt. per hour.

TABLE 4

	Cycles per Hour.	Time per Cycle.	Gross Weight.	Tons of Coal per Hour.	Energy per Cycle.	Energy per Hour.	Height of Lift.	Energy per Ton of Coal.	Cost per 1,000 Tons Shipped.	
									Water at 9d. per 1,000 Gals.	Electricity at 1d. per Unit.
Newport	40	Sec. 90	Tons. 710	444	280 gals.	11,200 gals.	Ft. 46	25·22 gals.	s. d. 18 ... 11	s. d. 10 ... 11
Rothesay Dock	43	84	596·8	362½	1·104 unit	47·481 unit	46	0·131 unit		

Referring to Table 4, it will be seen that the consumption of energy for coaling by electric hoists, including distribution losses, is 0·131 unit per ton of coal shipped when working to a height of 46 ft. This at 1d. per unit is equivalent to 10s. 11d. per 1,000 tons of coal shipped.

For coaling by hydraulic hoists the consumption is shown to be 25,220 gals. of water, which at 9d. per 1,000 gals. is equivalent to 18s. 11d. per 1,000 tons of coal shipped, showing a saving of 8s. per 1,000 tons in favour of electricity.

With reference to the comparative cost of generating hydraulic and electric power, it may be here mentioned that the above figure of 9d. per 1,000 gals. has been assumed as a fair average of the varying figures obtainable.

Respecting the question of economic working, experience has shown that even with the additional load due to the added power requirements at the dock—rendered necessary by the installation of two additional hoists—the actual costs as regards current, cost of maintenance, and upkeep of plant, are well within the figures originally estimated.

Attention might be drawn to the fact that the most economical speed at which to run tips for shipping coal is 100 to 120 ft. per minute; many tips run faster, 150 to 200 ft., but in consequence they have to wait for something, either trucks getting on or off, or for

e Great Lakes in America.

[To face page 619.]

the trimming work on the vessel. With the moderate speed of 100 to 120 ft. one truck per minute can be shipped with a tip of any height. The higher speeds entail heavier power plant, higher wages, more damage to wagons, and more wear and tear all round.

In comparing the merits of electric and hydraulic tips, Mr G. H. Baxter also states that for varying loads the electrical power adjusts itself quite economically to the load, a condition impossible to obtain in hydraulic tips, although considerable improvement has been obtained by the employment of multiple rams. This, however, can only be considered as a partial solution of the problem, as it depends on the discretion of the man in charge as to what number of rams he will use. As a matter of fact, when manipulating tips with trucks of varying loads, as is the case on the Clyde and other docks, it is practically impossible to make the necessary adjustments at every position for the most economical working, whereas electricity adjusts itself quite automatically to the varying conditions.

Mr Aspinall has collected some interesting information concerning the time wasted during the twenty-four hours in the use of coal tips, as well as of ordinary coaling cranes. This information was given by him when presiding at the Institution of Mechanical Engineers during the reading of the paper by Messrs Dixon and Baxter. Mr Aspinall does not mention the docks at which these figures were taken, but he mentions that 1,000,000 tons of coal are handled per annum.

TEST OF THREE MONTHS' WORK, SHOWING PERCENTAGE OF TIME
OCCUPIED IN EACH KIND OF OPERATION

	Two Hoists Combined.	Two Cranes Combined.
	Per Cent.	Per Cent.
Tipping and handling - - - - -	53·49	64·19
Waiting ships - - - - -	8·24	5·04
Waiting coal ¹ - - - - -	1·14	1·38
Adjustment of shoot - - - - -	3·07	...
Swinging and changing - - - - -	4·89	3·88
Trimming in holds - - - - -	12·25	8·24
Meal hours - - - - -	15·75	15·28
Other causes - - - - -	1·17	1·99
	100·00	100·00

This leaves the time actually occupied in tipping, handling, and packing the coal on to the boat 53·49 per cent. in the case of a hoist, and 64·19 per cent. in the case of a crane, being a clear gain of 11 per cent. in favour of the crane.

M'Myler Coal Tips.—The tips built by the M'Myler Manufacturing Co., of Cleveland, Ohio, are for the purpose of discharging cars which need neither be hopper-bottomed nor have hinged end doors for unloading. The trucks are tipped by rolling them over laterally when they have reached the required level in the tip. Such a tip is illustrated in Figs. 916 and 917, and consists essentially of a steel tower, similar to the Armstrong type of tip, which forms the guide for the cradle; the latter is provided with a rigid side towards the vessel to be loaded. Wire ropes are attached to the top of this side, passing upwards over the guide pulleys to a counterweight running in a groove at the rear of the tower. The hoist ropes are attached to a lower point on the same side

¹ This refers to the time occupied in getting the trucks on to the tip or on to the crane.

of the platform, beneath which they are passed under guide pulleys, rising from thence to the top of the tower and back to the hoist winch. The platform is raised by a combined action of the ropes until the side meets an adjustable stop which checks the descent of the counterweight. As the hoisting rope continues to pull it turns the cradle and brings the car in contact with the counterweight ropes, which hold it firmly against the rails whilst the load is emptied into an inclined shoot which terminates in a telescopic tube through which the coal is lowered and trimmed. This extension reduces breakage and assists trimming in the ship's hold, as it can be moved about to reach from side to side of the ship.

The later tips on this principle (see illustration) are of sufficient size to handle loads of 75 tons, including coal and car.¹ The machine is so designed as to take the truck as it is delivered by gravity at the foot of the incline, haul it into the cradle, and empty the contents into the vessel, after which the car is led out of the cradle on to the track for empties. It is claimed that this machine has discharged as many as thirty cars and 1,000 tons of coal per hour.

The Brown-Hoist Electric Coal Tip.—Fig. 918 shows a tip, which was erected by the Brown Hoisting Machinery Co. for the Hocking Valley Railroad Co., of Toledo, U.S.A. By means of this machine the 50-ton coal wagons are picked up and emptied sideways into a large shoot from which the coal is directed into the hold of a vessel.

The loaded truck is pushed on the cradle—which will take any sized truck—by a car-pushing device. The truck is secured in position by hydraulic clamps on top and sides, then the tip is started and the cradle slowly revolves until the car is in a discharging position. During this process the material flows into hoppers fixed to the cradle, each of which is connected with a transfer tube through which the material passes, these compartments being fitted with doors which are automatically released on touching the lower end of the transfer tubes. Each empty car is replaced by the next loaded car coming along, and is run by gravity to the empty track, the process already described being then repeated. Thirty cars per hour may be handled with such a tip.

Long's Coal Tip is the invention of Mr Timothy Long, of the Excelsior Ironworks, Cleveland, Ohio, U.S.A., and has been successfully put into operation at the Erie Docks, Cleveland.

The diagram, Fig. 919, illustrates the principle on which it works, although the one at the Cleveland Docks is at a higher level above the quay than the tip shown in this illustration. This apparatus consists of a cylinder mounted at each end on rails on which it can revolve, and large enough to receive the railway truck. Within the cylinder is a continuation of the outer track by means of which the wagon enters. It is clamped in position, and the cylinder is then caused to revolve towards the shoot by means of cables and a winch. Through this partial revolution the wagon is tilted sufficiently to discharge the coal into a shoot or hopper, after which the cylinder is rolled back to the starting point, where the wagon again assumes its normal position and is pushed out by a full one. The cylinder is 40 ft. in length and has an internal diameter of 11 ft., whilst the outer diameter is 16 ft. It consists of a strong framework, and has openings of sufficient size for the coal to pass through in the discharging position.

The capacity of this tip is stated to be three hundred trucks, or 7,500 tons of coal, per

¹ This tip has been fully described in a paper read by Mr J. D. Twinberrow before the Institution of Mechanical Engineers. See *Proceedings Inst. M.E.*, 1900, page 574.

day of twenty-four hours, and it is reported to have discharged three American bogie trucks into a vessel in three minutes.¹

Coal Tip by Pohlig, of Cologne.—Fig. 920 represents a coal tip built by J. Pohlig,

Fig. 918. Brown-Hoist Coal Tip.

of Cologne. Unlike those previously described, the railway truck in this tip is not taken up in a perpendicular direction, but at an angle of 45°. The truck to be unloaded is

¹ This tip was described in the *Scientific American*, 16th November 1895, page 312; also *Engineering*, 21st August 1896, page 211.

pushed forward upon the cradle and put into position. The cradle is fitted with four wheels and ascends on the rails, to the top of the inclined structure, where these rails are so arranged that as soon as the cradle has reached the highest point the front wheels are lowered sufficiently to put the cradle and truck in a position at which the coal will leave the truck. The engine and winding gear necessary for this installation are placed at any suitable point in close proximity to the tip itself. The cradle is so balanced that the winding gear has only to perform the actual work of elevating the coal. There is also a safety brake to prevent the cradle descending at an excessive speed, even if the cable of the winding gear should snap. The truck discharges its load into a hopper, from which it is fed by a shoot into barges. If the hopper is kept full there will be but little breakage in the delivery of the coal, and if carefully manipulated by means of the hand wheel the coal will leave the lower end of the shoot at the

Fig. 919. Long's Coal Tip.

Fig. 920. Coal Tip Built by Pohlig.

same rate at which it enters the hopper. With these tips the truck must always be elevated to the same level; they are therefore only suitable for non-tidal rivers and for vessels of uniform dimensions.

Hydraulic Crane Tip at Middlesbrough.—An entirely different type of coal-loading apparatus is illustrated in Fig. 921, and represents the movable hydraulic crane tip at Middlesbrough for loading coal direct from the docks into ships. It consists of a heavy pillar revolving on a built pedestal, which has an archway large enough to pass a locomotive and box wagons. The lower part of the pillar is carried in a footstep attached to the bottom of the pedestal above the archway, while the upper bearing of the pillar is formed by the top of the pedestal. The pillar carries jibs pivoted on a pin at its heel, the radius of which can be varied within wide limits by a hydraulic cylinder and ram placed in an inclined position at the back of the pillar, this ram being connected with the head of the jib by girders. The turning of the pillar and jib is effected by hydraulic cylinders placed at the back of the pillar, alongside the lifting cylinder, and acting on a chain which fits into a cupped drum round the top of the pedestal. The lifting mechanism is placed within the cheeks of the pillar, and consists of a hydraulic cylinder with rams and multiplying sheaves. There is also a tipping cylinder placed between the turning cylinders on the back of the pillar, and acting upon the tipping chain by which the rear end of the wagon is tipped up. Attached to the lifting and tipping chains is a cradle, for receiving coal trucks of either

Fig. 921. Hydraulic Crane Tip at Middlesbrough.

end or bottom door pattern, which fits into a seat which can be placed on the rails at any point without in any way cutting up the quay. The moving of the crane is effected by a hydraulic engine placed in the pedestal connected to the travelling wheels by shafts and gearing. This hydraulic crane has a lifting power of 15 to 30 tons, the height of lift being 66 ft. It was built by Sir W. G. Armstrong, Whitworth, & Co., Ltd., and is one of the latest developments of this kind of tip.

Similar cranes were erected at Avonmouth Docks and elsewhere, but with the

earlier tips it was necessary to have a pit between the rails into which the cradle for the reception of the railway trucks fitted. The crane at the Avonmouth Docks was built for handling coal from the local coal fields near Bristol, from the Radstock district; for South Wales coal which comes *via* Severn Tunnel, as well as for coal from the Forest of Dean and the Midlands. It lifts the truck on the cradle, which is then swung over the hatchway, the coal being tipped into the vessel. A similar tip is also used at Fleetwood. The crane travels on rails laid alongside the quay, and the cradle is so constructed that the trucks can be picked up from and deposited upon the rails at any point where the crane may be. The truck rests on the cradle which fits between the rails, so that the wagon may be run off at the opposite end to the point at which the loaded trucks enter; thus no sidings or turntables are required, and the train of wagons can be lifted and tipped in succession while the empty trucks are taken away on the same line of rails and in the same direction. The cradle is worked by the outside pair of chains, which are manipulated by a different cylinder and ram from the one actuating the tipping.

The tipping is arranged from the centre chain, which separates above the swivel, its two strands passing, at this point, over guide pulleys on the lifting beam above the cradle, to which both lifting and tipping chains are attached, the tipping chain being made fast to the rear end of the vessel. The lifting and tipping motions are each controlled by hydraulic power, and are operated by a man standing in a cabin in the front of the crane pillar.

A tip similar to that just described is installed at Bremen, Germany.¹ With this tip the coal truck to be discharged is run on a platform which forms part of the track passing along the quay side. The crane then picks up this platform with the truck upon it, and swings it round until the end of the car is over a large hopper, which is suspended from the upper arm of the same crane over the ship to be loaded. The truck arrives here in a horizontal position on its platform, as it has been elevated simultaneously by two sets of hydraulic hoists, one of which is connected to the front and one to the rear chain supporting the platform. By raising the rear chains the platform is tilted until the load has been discharged in this suspended hopper. The manipulator's cabin is in front of the crane, and in full view of the whole of the operations. The crane has been built for loads of 26 tons, the extension of the jib end being 26 ft., whilst the load can be raised to a height of 32 ft. The special jib which supports the hopper has a radius of 36 ft. and a lift of 45 ft.

This installation was built by C. Hoppe, of Berlin. Similar cranes, but of larger proportions, are being built in America.

Lewis and Hunter's Coal Tip at Cardiff Docks.—This system consists of a tip discharging its load on a level with the line. Self-discharging railway trucks can also be used, in which case the tip is not necessary. The tips, which are mostly used in this system, discharge the coal into a skip which holds the contents of the wagon, and the coal is elevated in this skip by a hydraulic jib crane, swung round over the hatch, lowered into the hold of the vessel, and there emptied. The crane is capable of travelling with its load along the quay wall, and is thus able to reach hatches at varying distances from the tip. With 10-ton wagons 29½ tons of coal have been tipped on board a steamer with one crane in an hour. One crane is therefore capable of working at the rate of 30 skip-loads per hour. The actual working rate in practice is, however, lower than this, and

¹ This tip has been described in a paper read by Mr J. D. Twinberrow on the "Capacity of Railway Wagons as affecting Cost of Transport." See *Proc. Inst. Mech. Engineers*.

the following record, published by the patentees, gives the time taken and the quantity of coal loaded with two cranes :—

Name of Steamer.	Quantity.	Time.	Tipping Operations per Hour with One Crane.
	Tons.	Hours.	Tips per Hour.
Lancashire - - -	5,817	20	14·5
Asama - - -	5,833	30	9·7
Knight Companion - -	6,411	34	9·4
Runic - - -	6,218	28	11·0
Rhympha - - -	3,303	16	10·3
Isle of Anglesea - -	2,033	13	7·8
Inchlonga - - -	4,133	27	7·7
Orsino - - -	2,781	12	11·3
Nedgid - - -	3,910	13	15·0
Wingates - - -	2,866	11	13·0
			Average, 11·0

A case may be mentioned of a steamer which went into berth at 5 P.M., and by 5.30 next morning had taken in 1,609 tons of coal, an average, after deducting stoppages, of 189 tons per hour, so that in this case 1,609 tons were shipped by one crane in eight and a half hours. The net loading time, after deducting delays, incurred in waiting for coal of the S.S. "Samoa" was twenty-eight hours, in which time she took in 7,484 tons of cargo and 1,750 tons of bunkers, or an average of 330 tons per hour. The S.S. "Iran," which was loaded by four cranes, took on board 9,213 tons of coal in a net loading time of twenty-six and a half hours, or on an average 347 tons per hour.

This system is the invention of Sir William T. Lewis (general manager) and Mr Charles Hunter (engineer) of the Bute Docks, Cardiff, and has been adopted by the Cardiff Railway at their Roath Dock, Cardiff.

Tips similar to the foregoing, in which the railway truck is emptied into ordinary and mechanical skips holding the full contents of the truck, which are then emptied into the ship's hold, have been designed by Mr G. T. Wart, colliery manager of the East India Railway; also by the Wellman-Seaver-Morgan Engineering Co., Ltd., Cleveland, Ohio. Besides these may be mentioned the Butler and Fielding system.¹

Other noteworthy devices are intermittent appliances in which the contents of the truck are emptied, either on or below the level of the rails, into a hopper from which they are transferred by a smaller skip to the ship, and then lowered into the hold.

Good examples of this type of tip are those erected in 1893 for the East India Railway; also the one erected at the Kidderpur Dock, Calcutta, both by Sir W. G. Armstrong, Whitworth, & Co., Ltd. In the latter instance each skip holds one half of a wagon load, or about 5 tons. The Rapier Coaling Crane may also be mentioned as well as the Beckett system, which is the invention of Mr W. T. C. Beckett, deputy agent and chief engineer, Bengal-Nagpur Railway, as they also belong to this type of coal tip.

¹ This system was fully described in the *Engineer* of 2nd June 1893.

CHAPTER XXXVI

COLLIERY TIPS OR TIPPLERS

THE coal tips described in the preceding chapter are mostly intended for the purpose of manipulating standard gauge railway trucks, but there is no reason why some of the types should not be applied to the purpose of emptying colliery tubs. Appliances for this purpose are, however, probably on account of their smaller size, of very different construction. They are generally known as "tipplers," and are built in a variety of forms, in most cases extremely simple, and too well known to require detailed descriptions, those delivering backward always being preferable, as

they cause less breakage than those delivering in a forward direction.

A few of the standard types are worthy of notice, and are here fully described. It will be seen that these coal tipplers are mostly of the type which discharge below the level of the rails.

Of the many improvements introduced for the purpose of minimising breakage, the devices for tipping coal with the least possible damage stand perhaps first, as the value of coal is in almost all cases dependent upon the size of the pieces received by the

Fig. 922. Perspective View of Rigg's Tipping Machines.

consumer. From its arrival in the tub or tram at the pit's mouth each transfer has the effect of more or less diminishing its value. Though the more friable kinds of coal sustain some damage by abrasion, more or less inseparable from transit in railway trucks, the most serious injury is generally incurred in tipping at the pit and in loading on ship-board. At collieries many different devices have from time to time been adopted with a view to preventing breakage, but these devices necessarily vary with the character of the coal in different districts. Thus, in Monmouthshire and South Wales the iron trams are provided with hinged end doors or bars, which are removed on the forewheels falling into recesses at the head of the screen; or else the necessary angle of delivery, about 35°, may be obtained by a tram being placed on an oscillating platform so arranged as to allow of its tipping to the required angle of clearance.

The so-called "box-tubs"—that is, tubs having no doors—are also variously tipped in balanced and unbalanced frames either backwards, forwards, or sideways on to the screen, sometimes under the control of a brake. In cases where the coal is not heaped above the top of the tub, a horizontal door is sometimes shut down upon it, and not

released until the tub is inverted over the screen. All these methods are bound to cause a certain amount of breakage, and are therefore superseded in modern collieries by more scientific tipplers.

Rigg's Colliery Tippler.—A tippler which greatly reduces breakage is that designed by Mr James Rigg, of London.

The rotating bonnet which receives the tub is so balanced that the position of the centre of gravity depends upon the tub being loaded or empty, and therefore causes it, under control of the brake, either to tip forward and empty itself, or to return unloaded. Within this bonnet is a horizontal hinged door, which has an important function to fulfil, as at whatever speed the machine may be working, this door will act as a regulator to the flow of coal, while gradually but steadily yielding to its pressure. In reality it combines with the shoot in spreading the coal over the screen or sieve, into which it is generally discharged.

Fig. 923. Screen Receiving Tub-load of Coal.

Fig. 922 gives a perspective view of these tipping machines working in connection with Rigg's curved balanced screens.

The diagram, Fig. 923, shows the screen in its normal position receiving a tub-load of coal, which passes down the incline and is gradually brought to rest under the lower screen bars, as shown in Fig. 924. The brake is again released, and the screen returns to its starting position to receive another load, these operations being effected during the period necessary for changing the tubs in the tip above. The slack or small coal which has been eliminated by the screen is received in the fixed hopper shown and thus passed into its own trucks.

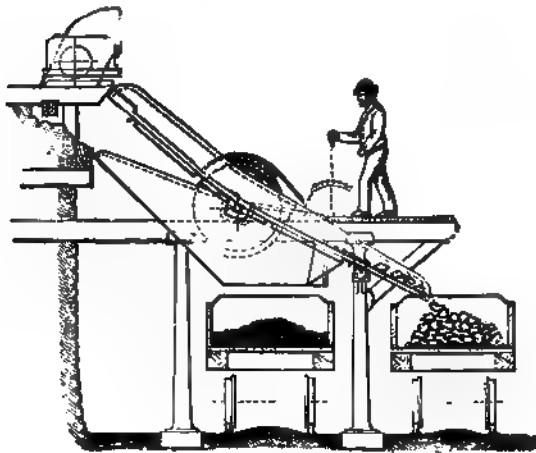


Fig. 924. Screen in Stationary Position.

use in this country. It is, of course, much smaller than the three-tub tippler (to be next described), and does not require any more height at the rail level than an ordinary power-driven tippler.

It was originally built of cast iron, but Messrs Heenan & Froude, Ltd., who have taken up the manufacture, are building it of mild steel for the handling of large material.

Fowler's Patent Gravity Tippler.—During the past few years this tippler, which also works by gravity, has come into considerable

It is claimed that thereby the diameter is decreased, the cost of construction reduced, and the durability of the tippler enhanced. It has a tipping capacity of eight tubs per minute. The tippler is also fitted with an ingenious device which holds the tub in position in the cage by a system of automatic claws that grip the spindles of the tubs. This arrangement is perfectly automatic, and consists of four claws in each of the two compartments. When the tippler is empty for the ingress of a tub, these claws are backed clear out of the way, but as soon as the tippler commences to revolve, the claws

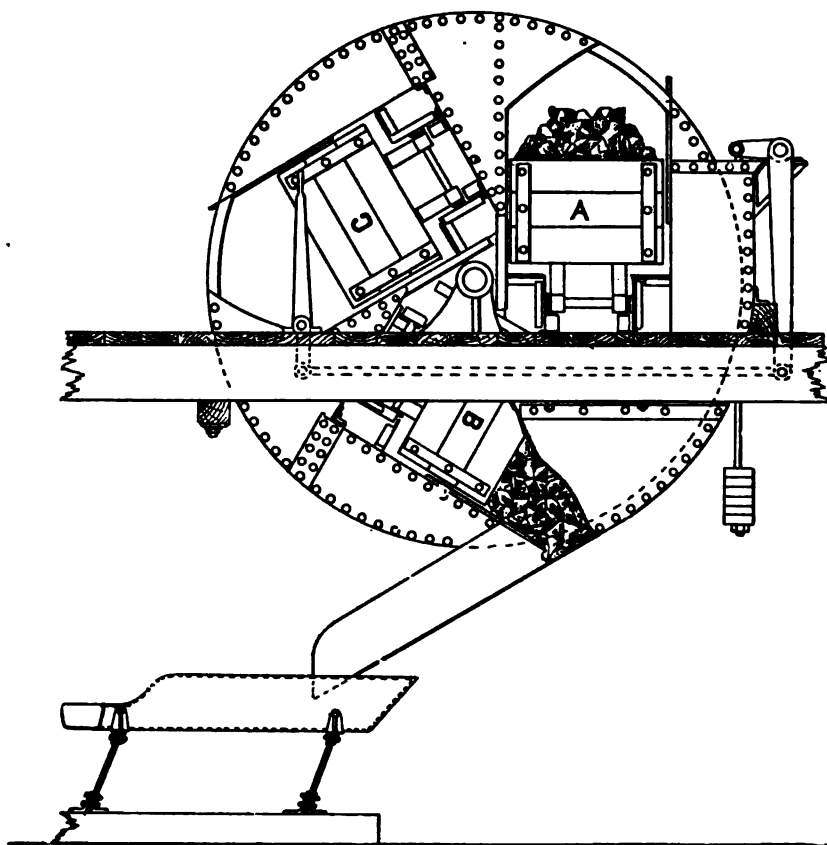


Fig. 925. Sam's Coal Tippler.

immediately move out and tightly grip the tub till it again reaches a horizontal position, when they automatically release their hold.

Sam's Coal Tippler is a modification of the tip previously described, and combines the simultaneous handling of three tubs, so that the speed at which each tub is unloaded does not exceed the speed at which ordinary tubs are cleared.

It is also built by Messrs Heenan & Froude, Ltd., and has several excellent features. It has hitherto only been used for emptying colliery tubs.

This appliance is illustrated in Fig. 925, from which it will be seen that the tippler contains three compartments for three tubs which run in one cage, the rotation being caused by the weight of the loaded tub A. The *modus operandi* then is as follows:—

The loaded tub from the weighing machine is run into the tippler with sufficient

velocity to eject the empty tub at the other end by the impact. When at rest the tippler is held in position by two powerful brakes which pass round the two end rings. These brakes are actuated by a lever arrangement under the control of the attendant.

On the movement of a lever the brakes are released, and the tippler rotates one-third of a revolution, and is brought to rest in that position. This brings tub c into the position just vacated by tub A. c is then removed and replaced by a new and full tub as before. The tub A takes up the position shown at B, in which position the side of the tippler stands at an angle of 30°, an oblique plate at the side of the tub forming a temporary hopper into which the coal is discharged, the coal being held in this position until the succeeding tub is tipped, when the tub previously emptied takes the position at c. This is of great importance, as the stop at point B gives the tub time to gently empty itself. This tippler can be made with a cage which will automatically arrest itself in three different positions, but it is generally found more convenient to allow it to be manipulated by an attendant.

These tipplers are made in sizes ranging from 6 to 10 ft. in diameter. They



Figs. 926 and 927. Diagrams showing Action of Rigg's Power-driven Colliery Tippler.

consist of two mild steel rings built up of channel steel and joined to the centre boss by channel steel arms of the same section, which are held together by gusset plates, as shown in the illustration. The end rings are joined together by side plates of $\frac{1}{4}$ -in. metal and also by angle irons which form the rails for the tub. The whole apparatus is suspended on a mild steel shaft of 4 in. diameter which revolves in two substantial cast-iron bearings.

The same arrangement for automatically holding the tubs in position while tipping is used with this appliance, as has been described in the case of the "Fowler" tippler. That is to say, four claws are made to automatically seize the spindles of the tub until it reaches a horizontal position, when they automatically release themselves.

Rigg's Power-Driven Colliery Tippler.—The tip on this system describes a rotary oscillation only, and not a complete revolution, as is generally the case.

This tippler combines all the advantages of the gravity tippler, with the increased speed necessary to enable a large output to be fed on to the picking belt. The speed of the oscillation is slow only during about 10°, while the coal passes from the tippler to the belt or to the intermediate jiggling screen.

The diagrams, Figs. 926 and 927, show the means by which the varying forward and return oscillations are obtained. Fig. 928 is a side elevation.

The shaft *c*, Figs. 926 and 927, is driven at a uniform speed, the pin *g* on the crank *h*¹ being connected to an arm, and the toothed segment *e*¹ communicating motion to the pinion *b*³ and also to the wheel *b*², which is geared into the rack *A*² attached to the

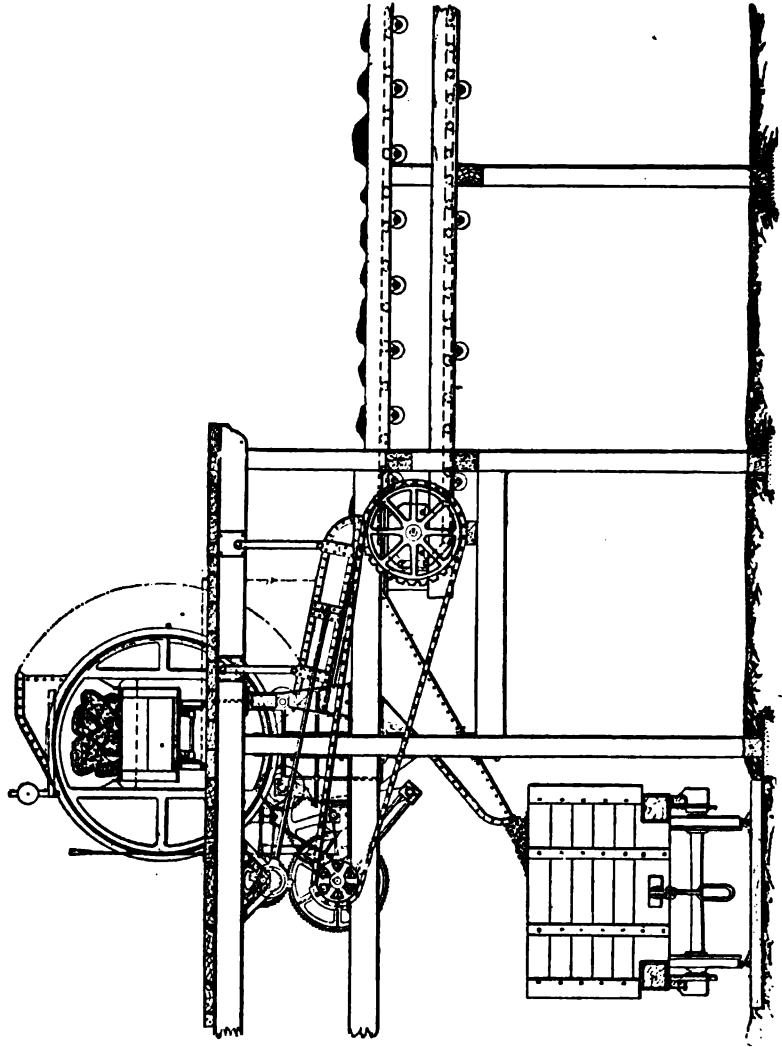


Fig. 928. General View of Rigg's Power-driven Colliery Tippler.

tippler *A*. One revolution of the shaft *G* causes the double oscillation of the tippler through the arc indicated by the dotted lines. It is important to observe that the three equal arcs, *g g*¹, *g*¹ *g*², *g*² *g*³, of this portion of the path of the travelling crankpin correspond, as stated, with the varying velocity of travel of the tippler, as indicated by the letters *a a*¹, *a*¹ *a*², and *a*² *a*³, and this variation, as well as the return of the empty tub, is well adapted to secure an extremely rapid motion when coal is not leaving the tippler, and a slow one prior to, during, and for a brief period after its delivery.

The Head-Wrightson Friction-Driven Tippler is of popular design, and is illustrated in Fig. 929. The frame consists of steel plates and angles securely riveted to the tippler rings. When stationary, the tippler is carried at the front upon two rollers, which run free in bearings, and at the back by hanging upon the stoppers hereafter described. The back friction driving rollers are keyed to a shaft which is constantly running.

There is a slightly flattened portion on both of the friction rings over the driving rollers, so that the tippler in its normal and upright position is not in contact with the friction driving rollers. At the back of the tippler shoot are two brackets, fitted with square sliding bolts connected to a shaft, which is provided with a hand lever, by means

Fig. 929. Photographic View showing Four Head-Wrightson Friction-driven Tipplers as installed at the Bank of a Colliery.

of which the sliding bolts are moved backwards or forwards. The sliding bolts are arranged to engage with an adjustable stopper attached to each tippler ring. When the bolts are moved backwards the friction rings are allowed to come in contact with the friction driving rollers, and the tippler revolves.

Just before the revolution is completed the stoppers on the rings rub against the ends of the sliding bolts (which have previously been moved into the forward position); the momentum acquired is absorbed, and the tippler comes gently to rest with the stoppers on top of the square sliding bolts. The back of the shoot to which this arrangement is attached being of thin steel plate, the bolts are not held perfectly rigid, but act as a spring brake on the friction rings, which latter, as well as the rollers, are of cast iron truly turned and bored.

The tippler can be arranged to work automatically by the addition of simple devices

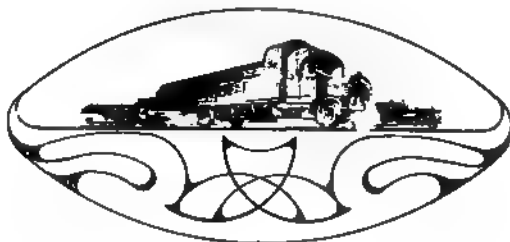
which cause the full tub going into the tippler to release the empty tub and push it out, automatically locking itself in. As the empty tub leaves the tippler it strikes a lever which automatically sets the tippler in motion, thus dispensing with an attendant.

It is claimed for these tipplers that they have the advantages of: (1) Simplicity, there being no springs, clutches, or complicated details; (2) smoothness in working, the construction being such that the coals are gently distributed into the shoot with a minimum of breakage.

Fig. 930. Multiple Tip at the Mines des Landres, Lorraine.

Multiple Tips.¹—A tip which will manipulate a whole train of small gauge trucks is shown in Fig. 930. It was built by G. Heckel, of Saarbrücken, for the purpose of depositing iron ore in an ore pocket, at the Mines des Landres, Lorraine. The whole apparatus is mounted on wheels and electrically driven, and accommodates six to eight trucks. The advantage of having the appliance portable and mounted on rails is obvious, as it facilitates the filling of the silo from end to end.

¹ From an article by Fr. Tillmann, in *Zeitschrift des Vereines deutscher Ingenieure*, 12th March 1910.



CHAPTER XXXVII

LOADING COAL INTO SHIPS OTHERWISE THAN BY TIPS

COAL tips or hoists, which form the subject of Chapter XXXV., have the obvious disadvantage that railway trucks weighing about 5 tons have to be raised 50 or 60 ft. in order to empty 10 tons of coal into the ship's hold. During the discussion on his paper, "Mechanical Handling of Material," before the Institution of Civil Engineers on 24th February 1903, the author pointed out that it would be more economical to load coal by means of a tipping device on the level of the rails in a track hopper by gravity, and then raise it by means of inclined elevators or conveyors to the necessary level. The elevator, or part of it, could be made to swivel like a jib, and thus be raised or lowered to suit the position of the ship to be loaded.

Mr Roger T. Smith, electrical engineer of the Great Western Railway, enters more fully into the subject in the following five remarks on the advantages of the belt conveyor over the tip for shipping coal :—

"1. That for the same capacity the initial cost of the conveyor was from one quarter to half that of a tip or a hoist.

"2. That the load factor at which the machine worked was 80 to 90 per cent., because the maximum load was the same as the average load.

"3. That there was a greatly reduced weight on the tower supporting the free end of the conveyor (which was adjustable) as compared with the weight of the hoist, thus lessening the cost of foundation or the cost of the jetty, if a jetty were necessary.

"4. There was a possible saving in land for sidings, because instead of all the sidings having to come end on, as was necessary for the tip or hoist, they were much better arranged parallel with the quay.

"5. There was an enormous reduction in the maximum demand on the power supplied."

It might, however, be mentioned that the quay space required for such loaders would prohibit their use on the Clyde and at some other ports.

The economy of coal loaders on this system depends principally on the life of the belt, and as good quality cotton and rubber belts can be obtained for a guaranteed delivery of 1,000,000 tons of coal, the cost per ton of coal shipped is infinitesimal as far as the wear of the band is concerned.

Mr R. T. Smith also gives the following comparisons of power consumed for different systems of coal tipping and shipping :—

Newport Hydraulic Hoist	-	-	·164	kilowatt-hour per ton of coal raised, 46 ft.
Rothsay Dock Electric Hoist	-	·131	"	"
Fowey Electrically driven Conveyor	·095	"	"	"
(exclusive of tipping)				

It has now been fully demonstrated that such methods of loading coal and other materials into ships are far superior when local conditions permit of their installation.

Some earlier coal tips have actually been replaced by devices of the class with which this present chapter deals. Band conveyors are more generally used for this purpose, but before describing coal shippers in which band conveyors form the principal feature, particulars of a few other methods are given.

Before, however, proceeding to describe more fully coal shippers in which a belt conveyor forms the principal feature, we will give details of one or two other methods.

Coal Loaders at the Japanese Port Miike.¹—The quay of the new dock of the colliery at Miike, the property of the Mitsui Mining Co., is 460 yds. long, so that three large steamers can load at the same time. In close proximity to the quay wall is an area set aside for storing coal. This is shown in Fig. 931, which represents a section through the general loading arrangement, which is as automatic and labour saving as it is possible to make it. The coal is brought, after classification by standard gauge trucks holding 8 tons, from the five pits of the company; it is then either loaded immediately into steamers by two new loading devices or it is deposited on the storage heaps. There are five elevated lines of rails serving these stores, with five tunnels

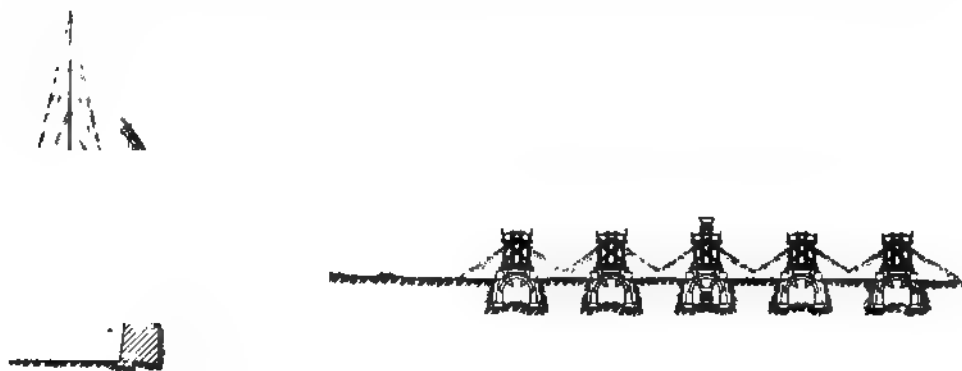


Fig. 931. Elevation showing Arrangement of Coal Store and Loader at Port Miike.

under, so that, with the exception of a little trimming, the coal may be withdrawn at a great rate of speed, and with a minimum of labour. The tunnels are each nearly 200 yds. long, and the dépôt will hold about 50,000 tons of coal. The loading system is on similar lines to a modern blast-furnace hoist, but portable. Fig. 932 shows a perspective drawing of one of these loaders. From Figs. 931 and 932 it will be apparent that the receiving ends of the loaders move along the quay in a trench, parallel to the quay wall, and this is widened into bays or pockets, separated by piers or walls from each other, over which two lines of rails are laid which feed the loaders, *i.e.*, one for the full trucks nearest the coal store and the other for the empty trucks nearest the quay.

The loading apparatus with its details may best be seen from Figs. 933 and 934, the former of which also shows one of the loading bays in section. Centrally in each bay is fixed what forms the lower terminal of the track of the loader, which latter is placed centrally with one of the bays. At the back of each bay is an adjustable hopper shoot, so that the contents of an 8-ton truck can be transferred instantaneously to the dumping

¹ The description and illustrations of these loaders are taken from an account by H. Nölke, in *Zeitschrift des Vereines deutscher Ingenieure*.

Fig. 932. Perspective View of Coal Loader at Port Miike.

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Fig. 933. Diagram of Coal Loader at Port Miike.

skip *f* of the loader. The inclined plane of the structure forms an angle of 50° with the horizontal; it is provided with the rails *aa* and *b*, which are fixed to the structure, whilst a third pair of rails *c* is arranged in a telescopic manner, so that the rails with their upper or unloading terminals may be moved at will between the limits c_1 and c_2 in order to accommodate themselves to the tide and the size of the ship to be loaded. As soon as the loader has been moved centrally with the bay where the coal is to be loaded the

rails are coupled up at *q*; the gauges of the three lines of rails are 13, 14, and 15 ft. respectively; the upper ends of the rails *c* are bent first in a horizontal, then in a vertical direction, as seen in the highest position at c_1 . The dumping skip *f*, which is large and shallow, runs on two pairs of wheels, the foremost pair of which run on rails *b* and *c*, and have a flange in the centre, whilst the hindermost pair run on the outer rails *a*. In consequence of this provision, the skip tips over and empties its contents as soon as the front pair of wheels reach the horizontal portion of rails *c*, as the back wheels remain on the straight rails *aa*. The dumping skip is shown in its highest and lowest unloading positions, the upper in full, and the lower in dotted lines.

The loading shoot consists of the four parts *k*, *r*, *t*, and *p*, and its lower portion is movable as a whole along rail *w*, between the points m_1 and m_2 , to allow of the necessary adjustment to suit all conditions for loading. The portion *p* allows of a telescopic movement between points *i* and i_1 , on eight rollers and guide rails *o*, by means of hand wheel *x*, to alter the reach of the loading arm. Portion *r* of the shoot is movable round swivel *s*, whilst *t* and *p* may likewise be moved round joint *u*; these movements are more particularly for the purpose of getting the shoot out of the way of the ship's tackle when moving into position. Valve *e* at the extreme end of the shoot

Fig. 934. End View of Fig. 933.

is adjustable to regulate the speed of delivery. The main portion of the shoot *k* is fixed at its upper end to rails *c* by joint *l*, and at the lower end is supported by the two wheels *m* running on rails *n*, which latter are parallel with rails *c*. Part *r* is hinged on to *k* by *s*. The upper end of portion *t* is hinged by *u* to the sliding blocks *v*. All adjustments of the loading shoot are such as to enable the operator to hold them in any position within their travel.

The hauling rope runs over guide rollers 1 and 2, and also over drum 3, and is fixed

to the winding drum 4. The two ropes 5, which manipulate the rails *c*, run over rollers 6, and are fixed to the drums 7; whilst the ropes 8, for raising and lowering the main portion of the shoot, run over rollers 9 to drums 10. The sliding blocks *v* are likewise joined to their ropes 11, run over rollers 12, and to their drums 13; whilst a second pair of ropes 14 proceed from the lower portion of *v* over pulleys 15 and 16, also to drum 13. The three pairs of drums 7, 10, and 13 are all on spindle 17, to the outside end of which is fixed a further drum 18, which receives motion for the shaft by rope 19 from drum 20 over guide 21. The lower end of the shoot portion *r* is manipulated by rope 22 running over guide rollers 23, 24, 25, 26, and drum 27. In a similar manner is shoot portion *t* manipulated by ropes 28 and drum 29. Spindle 30 carries the drums 29 and 31, and from the latter rope 32 leads over guide 33 to drum 34. It will thus be seen that all the movements of the rails *c*, the main portion *k* of the shoot, and the sliding block *v*, are manipulated from the same spindle and move therefore together. Minor adjustments can be made in the incline of the lower end of the shoot by the ratchet and tooth rack couplings (Fig. 935), which are inserted between the ropes 11 and 14, manipulating the sliding block *v*. After the loader had been at work for several months, an anti-breakage device was added in place of section *p*; it consists of joint 36 and bend 35, which is connected by a universal joint to the upper end of a telescopic shoot. The utility and the object of this addition are obvious; when the telescopic shoot is not required the extreme ends 38 and 39 may be fastened together by the rings shown, or the whole may be raised round joint 36 by the crane 40.

The motive power for these loaders consists of two electrically driven winches of 200 H.P. and 64 H.P. respectively, which are situated in the engine-house seen in Fig. 932. Direct current is used of 500 volts. The speed of the skips is about 3 ft. per second, so that the raising and emptying of the load and the return of the empty skips will take one minute; thus the whole cycle of loading operations gives a theoretical capacity of 480 tons per hour for each loader, each charge being 8 tons, but as a few seconds are lost for filling the skips, the actual average capacity is 5,000 tons per day of twelve hours, or say 416 tons per hour.

Fig. 935. Details of Coupling for Adjusting Shoot of Port Miike Loader.

Fig. 936 is interesting, as it gives a view of the two loaders during their erection; it took forty-seven days to erect the first, and forty-two days for the second.

The principal advantage of this loading system over that of the usual coal tips, in which the railway truck is raised bodily and emptied, is saving of time, as none of the tips accomplish the whole cycle of operations in so short a time. It is true that some tips have a much larger capacity, but the reason for that is, that much larger loads are handled with each operation, some of the trucks raised and emptied holding up to 50 tons of coal.

With the ordinary coal tip so much time is lost in moving the trucks to be emptied on to and off the cradle, whilst in the loading machines at Miike time is saved in this way, because as soon as one skip is filled with the contents of a truck, it ascends, and before it is returned empty, the next truck is ready to tip its load into it. In order to construct

a loader of a larger capacity it would only be necessary to provide an installation with a larger skip, as the time occupied by the cycle of operations would be practically the same for a larger load. The disadvantage of the loader is, however, one which varies with the quality of the coal, and may be so great as to more than outweigh its advantages by the breakage of the coal. With ordinary tips, some breakage is unavoidable, and is caused during the tipping of the truck, by the abrasion of the coal, and by the impact between the coal and the lowering shoot. We need not consider the damage caused in the shoot proper, as similar conditions will obtain with both types. Now, with the loader under consideration the breakage should, therefore, be about the same at the dumping point if loads of the same bulk are handled; or if anything the advantage will be with the loader, as the emptying of a shallow skip should injure the coal less than that out of a rectangular truck, because there is less drop and the thickness of the layer of coal is likewise less. Be this as it may, the greater part of the breakage caused in the transferring of the coal from the railway trucks to the

Fig. 936. View of Port Miike Loaders during Erection.

skips will be additional, so we may be justified in making an allowance for a little less breakage at the top of the loader. Now, this may be a serious matter if tender coal has to be handled, and yet with some coal it may be of so little consequence that the first named advantages of the loader more than balance the extra breakage. This installation deserves special attention as it differs so much from the appliances generally used in this country or in Europe or America. The general scheme is the design of Director Dan and chief engineer Kuroda, of the Mitsui Colliery Co., and the loaders were built by Head, Wrightson, & Co., Ltd., Stockton-on-Tees.

The colliery of Miike, the property of the Mitsui Mining Co., is the most important in Japan, with a daily output of 5,000 tons; and as the old harbour was only accessible to sailing ships, the company extended and modernised the harbour at a cost of 5,000,000 yen, or over half a million sterling, so that now large steamers can load there, whereas the coal had formerly to be transhipped from sailing ships to steamers at Kuschinotzu, over fifty miles away. The port of Miike, at which the above described coal-loading installations are now at work, is the most important centre of the Japanese coal industry.

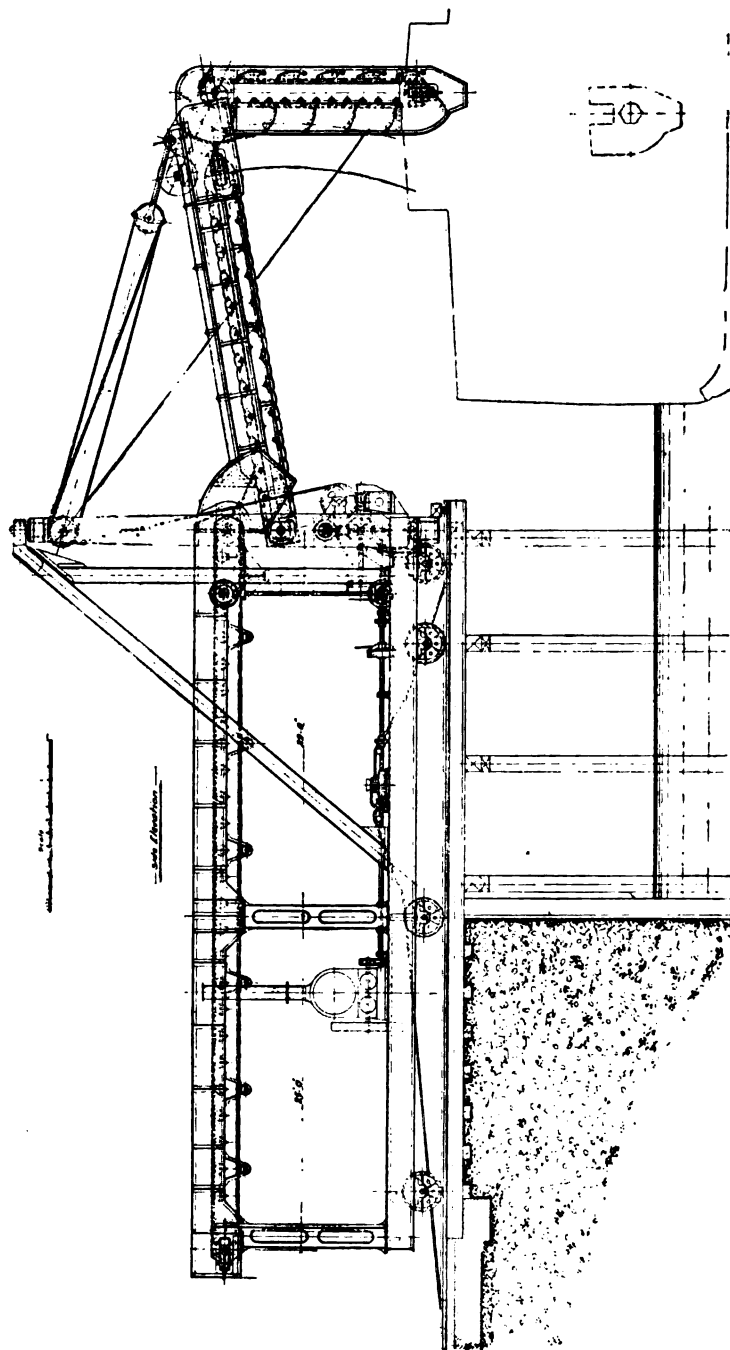


Fig. 937. The Wrightson Coal Shipper.

The Wrightson Coal Shipper.¹—The illustration, Fig. 937, represents a device erected at the staiths of the Cramlington Coal Co., in the Northumberland Dock on the Tyne. It was designed by Sir Thomas Wrightson, M.Inst.C.E., in conjunction with Mr Morrison, manager of the Cramlington Co., and was erected by Head, Wrightson, & Co., Ltd., of Stockton-on-Tees.

The coal is in this case brought in at a high level and discharged into the hopper immediately above the level of the first conveyor. At the lower end of the hopper a door of a size to allow the biggest pieces to pass permits the coal to run out on to the inclined conveyor. This conveyor, in moving forward towards the quay, draws the coal gently down the slope through the door, taking a layer of coal of a certain thickness, which travels to the edge of the quay. It is at this point received by another conveyor mounted on a jib, the outer end of which can by gearing be lowered or raised to suit the level of the ship to be loaded.

The coal is carried on this second conveyor until it arrives at the end of the jib, the position of which is so adjusted as to plumb the hatchway. Suspended at the end of the jib are a pair of vertical chains moving in a trunk; these chains have large trays upon each alternate pair of links, and in turning round the top drum, the back of the advance tray and the front of the following tray form hoppers. The coal from the end of the jib belt is directed into this naturally formed hopper. As the trays clear the top drum, they slide at an angle down the trunk, the coal being gently lowered until it reaches the level of the coal in the hold, where it discharges itself as the chain passes over the lower drum of the device.

The speed of the different conveyors is as follows: The shore conveyor travels at 40 ft. per minute, the jib conveyor at 60 ft., and the hanging conveyor at 52 ft. per minute.

The whole machine is self-contained upon a platform which can be moved backward and forward by the same power that drives the conveyors. In addition to this loading of the coal, some of the trimming is effected by the machine, as the jib is so arranged as to slew right and left over a space equivalent to the length of the hatchway. The vertical trunk, being upon the swivel joint at the end of the jib, can be deflected into a position which enables the coal to be delivered under the coamings of the hatchway, thus saving a portion of the cost of trimming, and the further breakage involved in that operation.

The conveyors are all driven by an engine with a pair of 10-in. cylinders, the power expended being about 20 H.P. The man in charge can control the speed of the conveyors as well as the raising and lowering of the jib, and the racking in and out of the platform, by means of levers and clutches placed in convenient positions. As an alternative to the retarding conveyor, a large rectangular or circular box or trunk can be suspended from the jib to receive the coal from the second conveyor. A large valve is arranged at the bottom of this trunk, which, on being opened, allows the coal to flow into the hold of the vessel at the same speed as that at which the top is being filled from the conveyor, thus keeping the trunk always full. This valve can be controlled by a cataract or other form of brake, and so made that after the trunk is emptied the valve rises to the top ready to receive the next supply of coal.

Coal Loaders at Grimsby.—In order to load coal into ships with a minimum of breakage, the appliances shown in diagram, Fig. 938, have been installed at Grimsby. This loader is similar to that in the Northumberland Dock on the Tyne (see above), but at Grimsby the coal is first unloaded from the trucks by a tip discharged at the level of

¹ *The Engineer*, 6th and 13th August 1897; and *Iron and Coal Trades' Review*, 3rd May 1901.

the rails on to an inclined band conveyor, which delivers on to a Marcus conveyor *b* running parallel with the dock wall and capable of delivering at a number of points under the portable loader proper to suit the position of the ship's hold. A steel plate conveyor *c* supported by a portable structure *a* delivers into the lowering device *d*. Although the coal is undoubtedly carefully handled by this device, considerable damage must be done to it by transferring it from the truck to the band, from this to the Marcus conveyor, and then again from this to the lowering device. There are two such installations with a capacity of 1,000 to 1,200 tons per hour each.

The Loading of Coal on the Humber.—In order to cope with the increased trade created partly by the development in the South Yorkshire coal field, the Hull and Barnsley Railway Co. have erected and put into use upon the western portion of their new pier at the Alexandra Docks, Hull, two electrically driven coal conveyors, by means of which coal is being shipped at the rate of 600 tons per hour over each conveyor, the

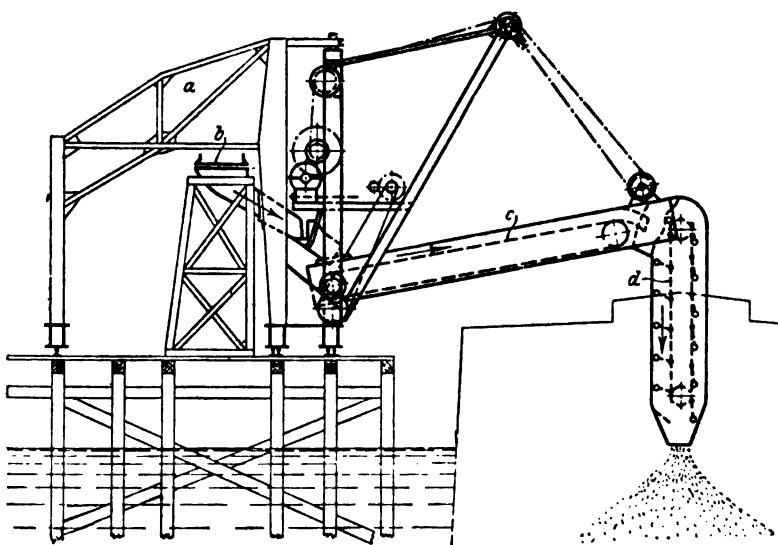


Fig. 938. Coal Loader at Grimsby.

total being 1,200 tons when the two appliances combine their efforts on the same steamer. They have since added a third conveyor of the same capacity.

The question of breakage of coal has for a long time engaged the attention of the exporters, and in this connection consideration has been paid by the above named railway company to the necessity of reducing breakage to the lowest possible minimum, and the design of these new conveyors is calculated to achieve this end.

The loaded wagons gravitate to a turntable, then to a hydraulic tip, and the coal when tipped slides out of the wagon into a hopper, and on to an inclined rubber belt placed beneath this hopper, which immediately conveys the coal to an adjustable telescopic shoot which is capable of reaching the coamings of the ship's hatchways, and is provided with a lateral shoot to reduce trimming. The empty wagon passes over the turntable and thence to the empty sidings to make room for the next loaded wagon, which follows immediately in its wake. The conveyors manufactured by Spencer & Co., Ltd., to the requirements of Mr R. Pawley, the engineer of the Hull and Barnsley Railway, are similar in design with the exception of the difference of a few feet in length. Each

apparatus consists of an endless band conveyor 42 in. wide, and approximately 475 ft. long, running at a speed of 400 ft. per minute, and fed by a tipping gear and hopper, at the shore end, delivering the coal at the water side by a system of adjustable jib and steel shoots.

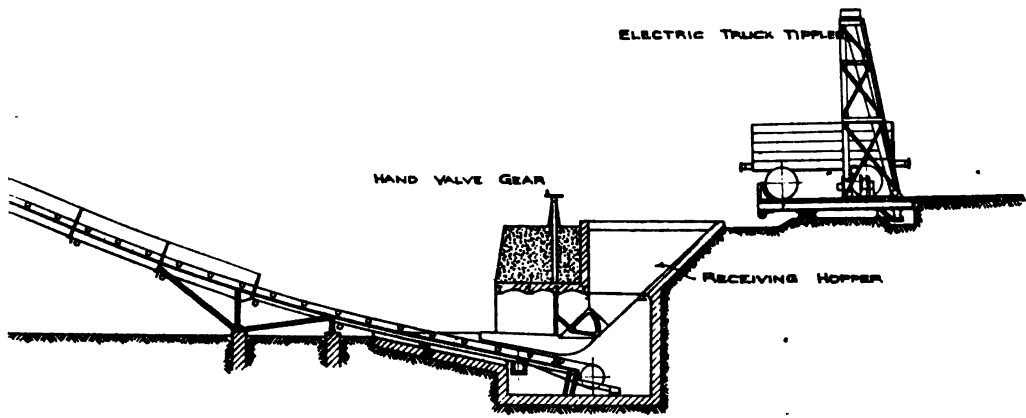
In order to obtain the advantage of an entirely unobstructed area at the top of the receiving hopper, the rail girders along the top, instead of being fixtures, are carried by substantial brackets from longitudinal fulcrums, and are carefully balanced, so that by means of a series of levers connected with the hydraulic ram, these girders swing outwards just previously to the tipping of the truck. In order to further avoid the breakage of coal, a steel tipping plate or apron is provided at the hinged end of the cradle, which rises from the top level of the hopper to the height of the wagon floor. A continuous surface is thus formed, down which the coal may slide gently into the hopper.

The troughed band conveyor receives a continuous feed from this main hopper by means of an adjustable gate actuated by hand wheel and gear. The outward end of the conveyor is carried by a hinged and balanced jib, giving ample vertical play. The shoot at the main jib end is telescopic and capable of a radial motion, extending 15° on either side of the centre line, whilst the further end of this shoot is provided with a second radial shoot, having circular ball bearings, and enabling delivery in the vessel's hold to be made over a complete circle if required. The luffing movement of this second shoot and telescoping of the first shoot are performed by hand through chains, chain wheels, and worm gear. It will thus be noted that not only is a gentle delivery of the coal ensured by these means, but the plant is thereby capable of loading out to any size of craft at any state of the tide, and delays to shipping are avoided. The control of the winches for hoisting and lowering the main jib and slewing the main shoot, is conducted from the driver's cabin placed in front of the substantial steel structure at the end of the jetty.

The driving power is furnished by an electro-motor situated in the motor house at the base of the tower, carrying the hinged end of the jib; here also is the necessary gear and drop tightening apparatus for automatically taking up any slack in the conveyor band.

A quite recent addition to the coal loading devices at the Alexandra Docks, Hull, consists of band conveyors with jib extensions, which latter can be raised and lowered

Fig. 939. General View of the New Coal Loading Installations at the Alexandra Dock, Hull.



ock Company.

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to accommodate the conveyors to the variations in high and low tide (22 ft.). There are two units which are practically the same in all respects, except for a few feet in length; the longer belt conveyor is about 470 ft. from centre to centre, and the total length of the conveying band is 970 ft., and its width 42 in. The belt used is a "Lincona," 8-ply, balata one, $\frac{5}{8}$ in. thick; the band speed is 9 miles per hour. A capacity of 600 tons per hour was stipulated for, but 860 tons have been loaded within that time. This plant was also built to the design of Mr R. Pawley, the Hull and Barnsley Railway Co.'s engineer, by Spencer & Co., Ltd., of Melksham. Fig. 939 gives a general view of both units, and in the foreground on the left the coal tip may be seen which feeds one of the conveyors.

Coal-Loading Plant at Port Talbot.—This plant was also built by Spencer & Co. for the Port Talbot Railway and Dock Co. It deals with 700 tons of coal per hour, the band conveyor being 207 ft. long by 42 in. wide.

The conveyor is fed at the shore end from a large steel hopper beneath the rail level. The contents of the railway wagons are emptied into this hopper by means of a double set of hydraulic tips, with two hinged rising and falling platforms working in opposite directions, which have this advantage, that the wagons need not be turned if they do not happen to arrive with the end door foremost. A series of gratings are provided in the hopper for the elimination of fine coal and dust, which is taken by subsidiary shoots to an elevator which delivers it to railway wagons on another set of rails. The plant is driven by electric power, the motor and driving gear being situated in a building between the fixed and hinged portion of the conveyor, and the loading-out operations are controlled from the driver's cabin erected above the steel structure upon the edge of the quay.

Another plant also for the Port Talbot Railway and Dock Co. was supplied by Fraser & Chalmers, and comprises a travelling and a stationary installation. The travelling one consists of an underground hopper receiving the coal from an electrically driven tip from end-door wagons on to an inclined belt conveyor, which later delivers on to two similar, but horizontal, conveyors, running parallel with the quay front, each fitted with a travelling tripper arranged to deliver the coal on to the belt of the travelling tower, which in turn delivers to the boat by means of a shoot. The stationary plant consists also of an underground hopper and an electrically driven tip delivering on to an inclined belt which feeds direct into the boats, the outer end of the conveyor being hinged, which gives a range of delivery similar to the other one, viz., from the water level to a height of 60 ft. above; both conveyors may therefore be used for loading all sizes of boats. The capacity of each plant is 1,000 tons per hour. The travelling plant is illustrated in Fig. 940.

The Coal Shipper at Middlesbrough.—An installation of the North-Eastern Railway Co. is illustrated in Fig. 941. The coal-carrying band is 42 in. wide and 310 ft. long, travelling up an incline of about 20° ; it has a capacity of about 600 tons of coal, and is fed from a hopper in the embankment under the railway line. The feed on to the band is regulated as in similar previously described installations.

The belt is kept clean by a revolving brush, in length equal to the breadth of the band, which is placed in contact with the band immediately the stream of coal has been delivered. The band now brushed clean assumes the flat shape as usual on the return run, and soon after leaving the brush it is led over two large drums, its path, while doing so, forming an irregularly shaped S. The object of this is to give the band such a firm grip as to ensure that no slipping is possible while working.

The band itself is of the composite kind. Its life is computed at two years'

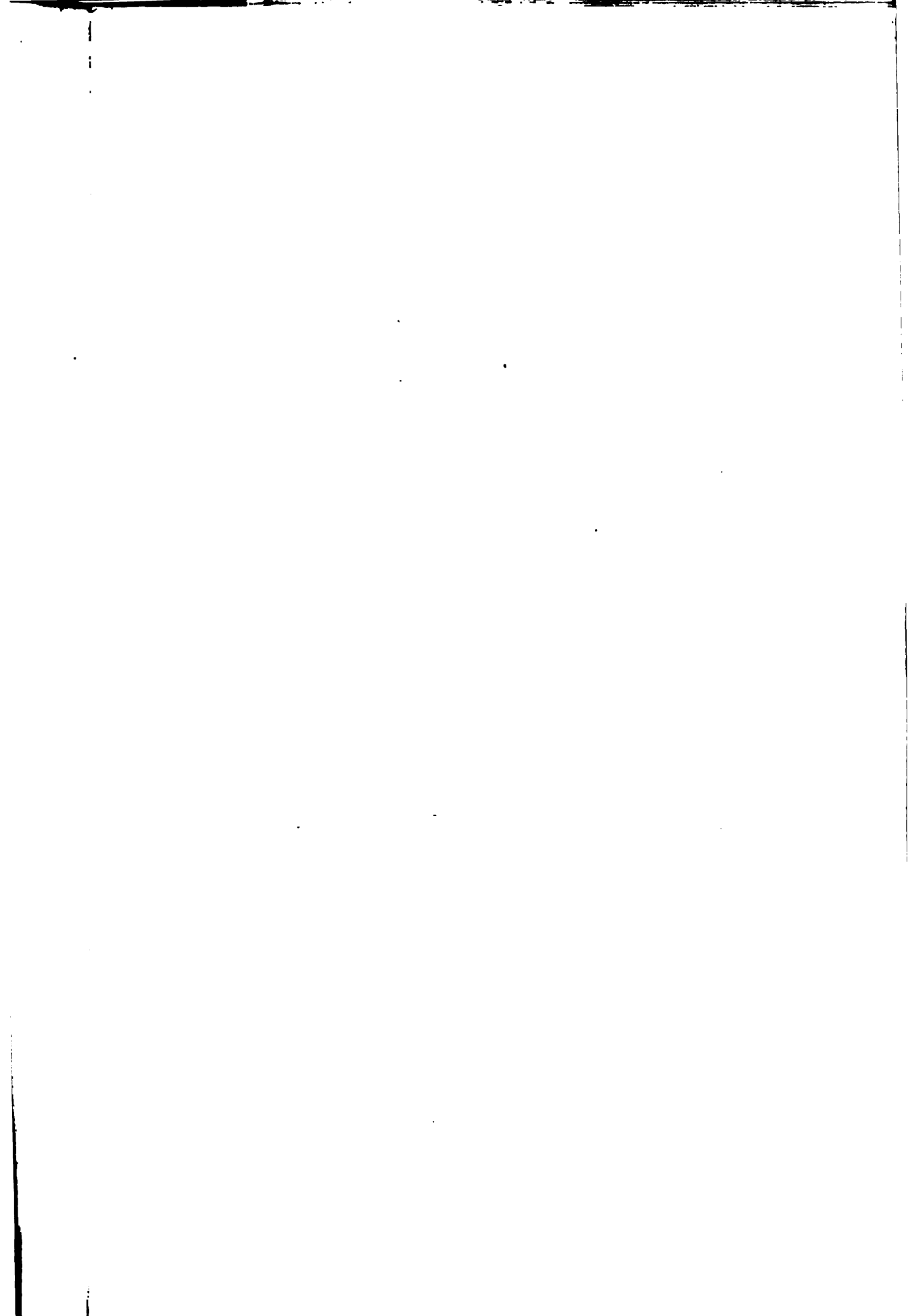
continuous running under full load, equal to carrying 1,000,000 tons of coal. Guard plates are fixed along each side of the band to prevent coal from falling off or being blown off by high wind. The whole is roofed in by radial-shaped galvanised sheets, extending from the tunnel in the embankment to the entrance to the machinery room in the tower. This band is driven by a Westinghouse shunt-wound direct-current motor running at a speed of 750 revs. per minute, with a voltage of 400. The loading jib which receives the stream of coal from the band through hinged connecting shoots is borne at the inner end by two trunnions resting in cast-iron brackets, which in turn are bolted to a pivoted frame. At a distance equal to about three parts of its length, the jib, which weighs 17 tons, is supported by a transverse steel bridle, in the centre of which is carried a cast-iron sheave. Through this sheave is rove the hoisting wire rope, which is led up to a set of sheaves in the bonnet or topmost structure, and is thence taken downward and attached to the cast-iron hoist drum. This drum shaft also carries a worm, which gears with the worm wheel on to which the hoist motor is directly connected. The

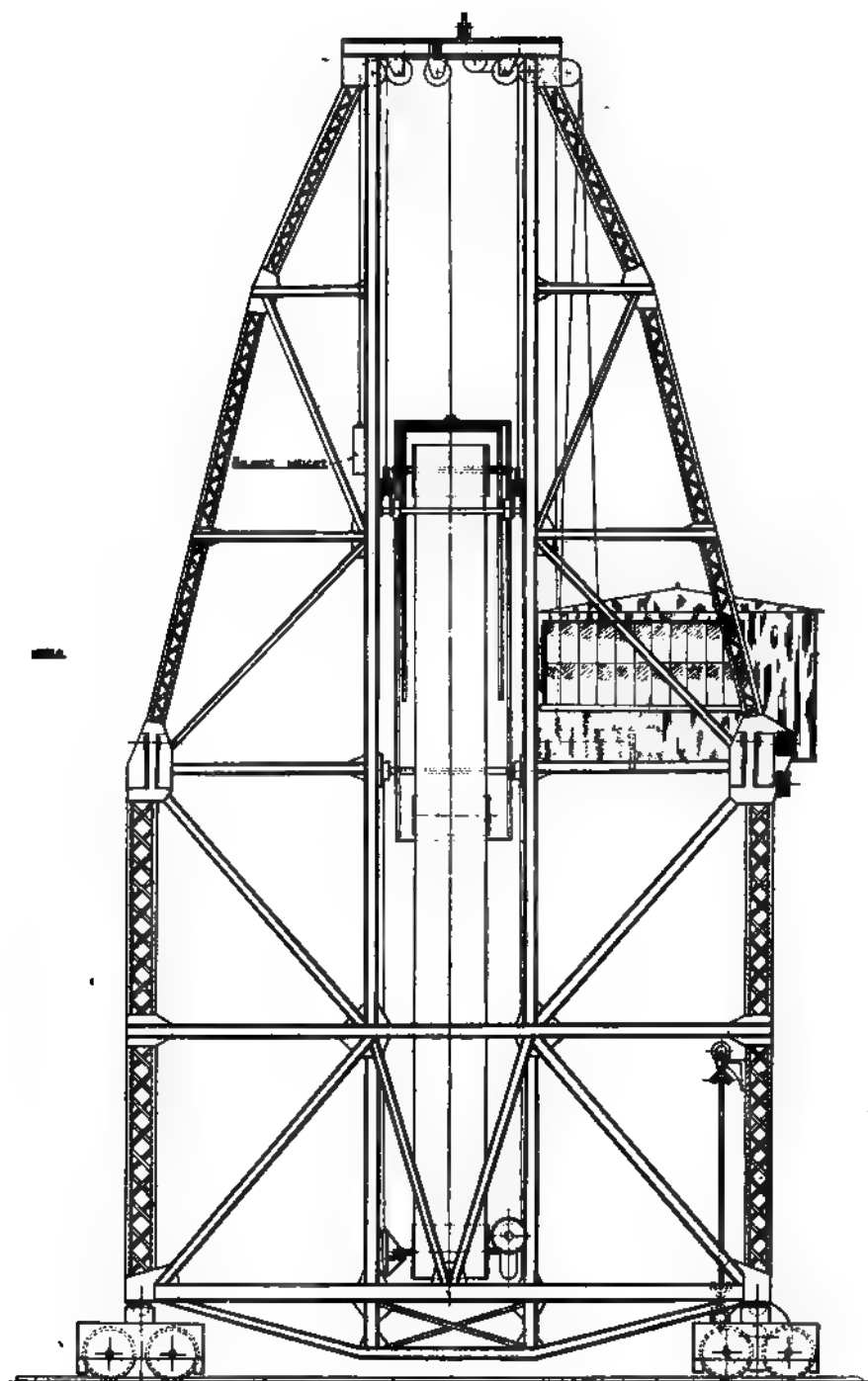
Fig. 941. Coal-Shipping Plant at Middlesbrough.

motor is a Siemens' series-wound machine of 10 B.H.P., running at a speed of 550 revs. per minute. The bridle also carries two stout wire ropes, attached one on each side of the sheave, which are led up to the bonnet in the same way as the hoisting rope, and which, after passing round sets of guide sheaves, have each a line of twenty-two counterbalance weights attached.

In the process of hoisting the jib the weights are automatically passed over one by one from the direct line of counterpoise to the line of the dead end by which they are supported. As the hoisting proceeds and the weights are taken up by the dead end, the line of weights on each side of the structure gradually assume the U-shape or festoon form, until, when the jib is housed and almost perpendicular, only two weights a side remain in direct counterbalance. Thus at whatever point in the arc described during the travel of the jib there is always the correct number of weights in direct counterbalance, the others being suspended from the dead end. The jib has a lateral travel of 12° each side of the centre line allowed for by the pivoted frame and limited by an ingenious arrangement of wire guy ropes. This is necessary to meet the fore and aft ranging of the ship taking in the cargo or bunker coal.

The highest position of the jib at which coal can be shipped is 18° above the





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horizontal. The coal is conveyed by means of an endless belt of steel plates or trays running the whole length of the jib, 54 ft. centres, driven through a friction clutch on the main shaft in the tower and operated from the driver's cabin in the structure. From this position the driver controls the whole of the operations, electrical and mechanical, the handles for which are all grouped within easy reach, whilst from the cabin window he can watch and guide the movements of the jib. When the jib is sufficiently low for the stream of coal to fall down it, there is, of course, no need to run the belt of steel trays. At the extreme end of the jib a throttle door is fitted to limit the opening for coal; this is controlled by a single wire rope from the driver's cabin.

It is claimed that the whole equipment requires no more for its safe and efficient control than a man of average intelligence exercising ordinary care. The installation, with the exception of the electric motors, was manufactured and erected by Spencer & Co., Ltd., Melksham, according to the requirements of Mr T. M. Newell, the chief engineer for the docks of the North-Eastern Railway.

Other examples are those at the Victoria Dock, Hull, of the North-Eastern Railway. Two belt conveyors, each 42 in. wide, are used for loading 600 tons of coal per hour to a height of 40 ft.; they have, however, done as much as 750 tons. Each of these installations is driven by a 100 H.P. gas engine.

At Hartlepool on the staith between the old harbour and the Victoria Dock are eight similar belt conveyors for loading coal, also handling 600 tons, with a maximum of 750 tons per hour; in this case only a 25 H.P. motor has been provided for each.

On the Tyne at the Albert Edward Dock several similar belt conveyors are installed, while at their Tyne Dock the North-Eastern Railway have five, these latter being the first to be used for shipping coal. They are also used at Blyth; while at Whitehaven a belt conveyor shipper has recently been erected for loading 500 to 600 tons of coal per hour, and this is fitted with the latest form of anti-breakage device consisting of a spiral shoot, resembling a spiral staircase, for the coal to slide down, which terminates in a revolving shoot at the bottom end for distributing the coal and thus saving the trimming.

Coal-Shipping Plant at Durban for the South African Railways.—This important plant is one of the latest designs for loading coal from trucks into steamers. It consists of a M'Myler Car Dumper or Tip capable of handling 75-ton trucks at the rate of fifty trucks per hour. This tip delivers the coal either to a belt conveyor or to a series of railway trucks with bottom door discharge which are handled by an existing transporter. The belt conveyor which receives the coal is mounted on an inclined gantry and conveys, elevates, and discharges on to one of two belt conveyors which run parallel to the quay wall. Each of these conveyors is provided with a travelling throw-off carriage or tripper which can discharge the coal at any point along the quay. The inclined conveyor is fitted with a Merrick Weightometer¹ for the purpose of accurately weighing the coal passing over the same.

The travelling tripper on the quay conveyors delivers the coal to the receiving hopper of a telescopic conveyor carried on a travelling tower (see Figs. 942 and 943). As will be seen from the illustrations, the conveyor with its tower has a very wide range of operation. It is capable of discharging coal at any height up to a maximum of 50 ft. above the quay level or a total height of 60 ft. above the water line. It can also be adapted to deliver at a distance varying from 8 to 30 ft. from the edge of the quay wall so that any size boat calling at the port can be coaled by this installation.

The great flexibility, which is a special feature of this loader, is obtained by the very simple arrangement of making it both hinged and telescopic, so that by a combination

¹ The Merrick Weightometer is described in Chapter XLIII.

of these two facilities the discharging terminal can be placed in any position required within the limits mentioned. Fig. 944 is a photographic view of this installation.

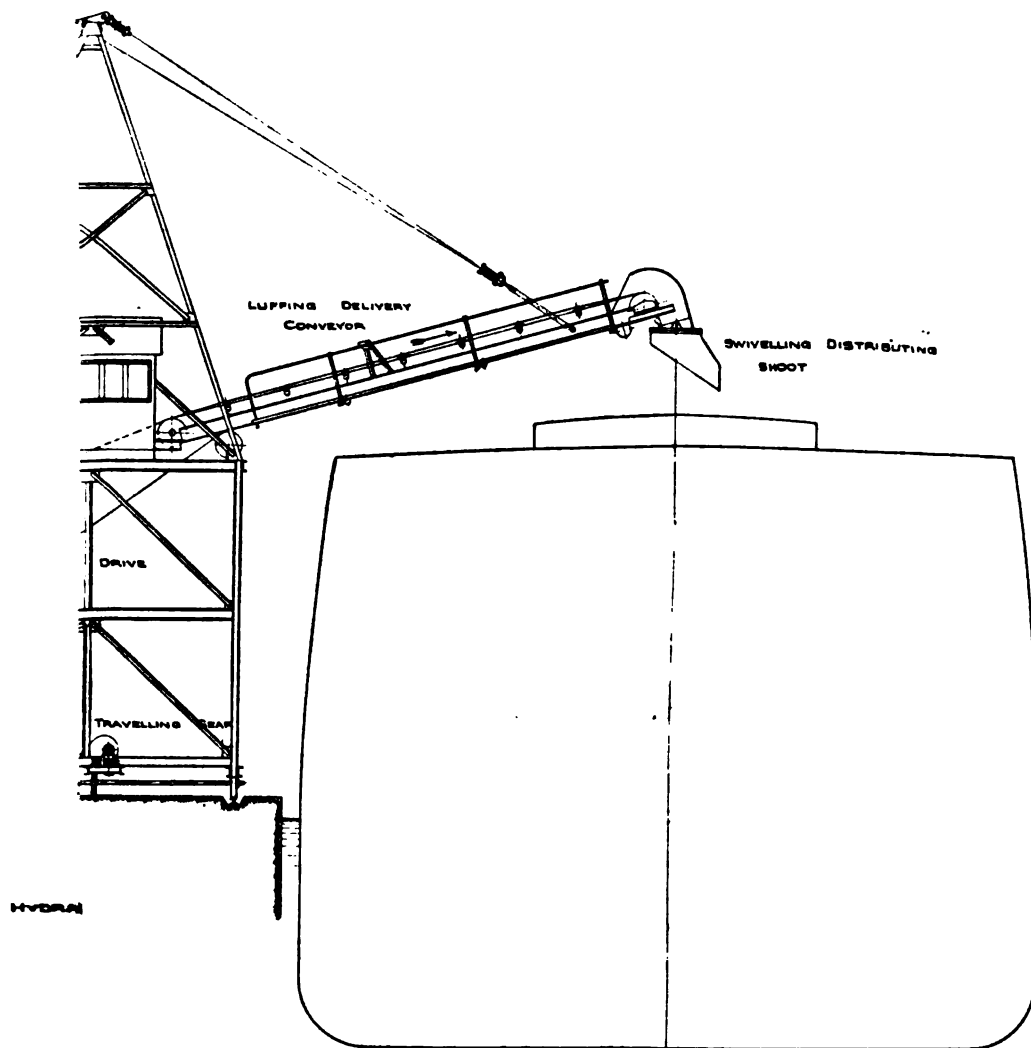
A telescopic anti-breakage lowering device is also provided which can be used either during the preliminary part or during the whole of the loading operation. The shoot is lowered into the hold of the vessel until the lower end reaches the bottom; the coal is then fed in at the top until the telescopic shoot is full, when it is gradually raised to allow the coal in the shoot to pass out at the same rate as it is fed in at the top

Fig. 944. Photographic View of the Durban Coaling Installation.

by the conveyor. In this way the coal can be lowered into the ship without a drop, and breakage is thus obviated. The plant has been so designed throughout as to handle the coal gently, with considerable success, and at no point of its transit has the coal a direct fall.

The guaranteed capacity of the plant is 700 tons per hour, but the actual capacity is over 1,000 tons per hour. The installation was supplied by Fraser & Chalmers, Ltd.

Coal-Shipping Plant at the Kidderpur Dock, for the Commissioners of the Port of Calcutta.—Two separate plants have here been installed, each as per Fig. 945. They consist of an underground hopper fitted with a hydraulic tip to unload



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the railway trucks. These hoppers feed the coal on to an inclined belt conveyor which in turn feeds a horizontal conveyor running parallel with the quay front, from which the coal is discharged by means of a tripper to a third or loading conveyor mounted upon a travelling tower.

The plant is arranged to feed coal to the holds of two vessels lying at two berths without moving them; thus considerable time is saved from the beginning to the end of the loading operations. The capacity of the plant is 500 tons per hour, and it was built by Fraser & Chalmers, Ltd.

In concluding this chapter, the gravity method of loading ships from staiths must be briefly mentioned.

Gravity Method of Loading Ships from High Staiths.—Such a system is in use at the Tyne Docks, near South Shields, and it is thus described in a paper read by Mr J. D. Twinberrow before the Institute of Mechanical Engineers:—

“Durham and Northumberland coals are transported in self-discharging railway trucks, the shipment being effected from timber staiths which contain hoppers fitted with spouts, projecting laterally over the vessels lying alongside. Tyne Dock, near South Shields, in Durham county, holds the record for the monthly and yearly tonnage placed on board. The arrangement is entirely self-acting, the wagons being run down the central roads by gravitation. In passing the short length of sharp inclination they acquire sufficient impetus to travel through trailing points on the rising grade, by which they are brought to rest and their positions reversed. They then take the points leading to the hoppers where they discharge their loads and run back on the ‘empties’ road. The ease and rapidity of the process, the small number of men employed, and the absence of costly machinery are features which stamp this plant with the character of an engineering feat of the highest order. If such staiths were introduced into districts where the end discharging wagons are in vogue, the erection of a simple gantry over each hopper would enable these vehicles to tip their loads, so that they could be continued in service until gradually replaced by high capacity hopper wagons. Bogie wagons of any length could easily be accommodated, and owing to the diminished friction of large wagons fitted with axle boxes for oil lubrication, the gradient of the roads might be reduced.”¹

The gravity system of loading is almost universally used in the United States and also in Spain where existing conditions permit of its use. It might be mentioned that an installation in the South of Spain can load as much as 8,000 tons in twenty-four hours from one double-sided installation, entirely by gravity, without the expenditure of any power, and with the assistance of only twelve men.

¹ See “Capacity of Railway Wagons as affecting Cost of Transport,” by J. D. Twinberrow (*Proc. Inst. Mech. Engineers*, 1900, page 573).



CHAPTER XXXVIII

MISCELLANEOUS LOADING AND UNLOADING DEVICES

THE ever-increasing cost of hand labour, as well as the ease with which electrical power can be led to, and connected with, portable mechanical appliances, has opened up a great field for labour-aiding and time-saving devices of such a nature, and it is most essential that such handling operations as cannot be performed by stationary devices, fettered to straight lines and right angles, should be executed mechanically, as only then will it be possible to reach into the furthestmost ramifications of our industrial undertakings and supply the mechanical connecting links which have hitherto been lacking.

Portable handling devices are intended for use in all cases where the quantities to be conveyed are too small for more costly stationary devices, and where the routes to be traversed are tortuous and subject to frequent changes. Such appliances are, therefore, applicable at docks for loading and unloading ships, in all factories for handling raw materials from place to place, merchandise in course of manufacture, and again for conveying finished objects to the warehouse. They are also used for conveying coal to small stock heaps, and from there to the boiler-houses, and for handling ores, etc. They are, further, applicable for dealing with packages, cases, bales, crates, sacks, and barrels.

Devices of this class can be mounted on castors, on road wheels, or on wheels suitable for running on rail tracks, and where too heavy to be wheeled they are made to be placed in position by cranes. Essential features of such installations are: rugged construction in order to withstand the rough usage to which they are often subjected, great simplicity in handling them, and the necessity of rendering them as fool-proof as possible, as the class of labour usually employed to operate and attend them possesses little or no mechanical intelligence.

Loading and unloading can be performed by joining several units of such portable devices together for the transfer of the material right to the spot where it is required. The advantage of scientific methods is not only smoother, quicker, and cheaper working, but also increased storage capacity, with the employment of fewer men.

It is a well-known fact that merchandise cannot be housed to the full capacity of the warehouse, store, or transit shed without stacking, and the cost of doing this by hand is now so great that it is often questionable whether it is more economical to pay for such hand labour or to sacrifice some of the available space by keeping it unoccupied. The introduction of stacking devices has therefore been a boon, as with them a warehouse can be filled to its utmost capacity at a minimum of expense.

Concerning the storing of bulk material, practically every industrial establishment, be it mine, railway, factory, or what not, stores some kind of loose material in bulk at one time or another, generally in the open, such material probably being brought by truck or wagon. Now, to stack such bulk material by hand is costly, and adds unnecessary expense, from 4d. to 1s., according to circumstances, to the cost of every ton so stacked; while by the employment of suitable stacking machines, 80 or even 90 per cent. of this cost can be saved. Such portable conveyors and stacking devices as are dealt with in this chapter do the work of from two to ten men, according to local conditions.

Portable plant is attractive for several reasons; in most cases it requires no foundations, and is applicable to a greater or lesser degree for the same class of work performed by more costly stationary plant, on account of its greater flexibility.

Combinations of two or more portable conveyors are often preferable to one single machine, especially when the distance traversed exceeds 30 ft., and it is hardly necessary to illustrate the great variety of possible combinations for loading, unloading, and reclaiming from the stock pile, etc.

In some of the earlier portable conveyors every unit is fitted with a 2 or 3 H.P. electro-motor in its under frame; they have only two road wheels and can be easily moved about. When used in multiples each unit is placed at a slight incline so that the first delivers high enough to drop its load upon the next, the feeding end of which is below the feeding end of the first, and so on. This refers particularly to band conveyors; but since the advent of the slat conveyor for portable devices it has been found much more convenient to use power-driven units only occasionally, one of which is capable of providing driving power for three or four other units. There is, moreover, the advantage, in case of any necessary repairs, of having the motor in a more accessible position than under the conveyor, housed in its framing. The latest portable devices can be coupled to each other, and convey on the same plane. In this way freight can be delivered in any desired direction, and the conveyor may terminate with a piler or stacker, either in a straight line or at an angle to it. At the receiving or discharging end a section can be arranged to work at a slight up or down gradient, so that the freight can be received and delivered, either above or below the level of the standard height of the units; in this case the ends in question are supported at the height required by portable trestles. The capacities of the machines are only limited by the rate at which the labourers can put the cases or sacks on and take them off at the other end.

Modern portable conveyors are generally made up in lengths of from 15 to 60 ft., mounted on wheeled trucks and built up in standard sections to give any desired length in multiples of 3 ft. The wheels of the trucks may be made to swivel in order that the conveyor may be traversed or made to describe a circle with the loading end as the centre. Alternatively, the conveyor may be supported in the middle and suspended from a wood track or wire cable by an overhead trolley. For ordinary bulk materials the maximum practicable incline is about 21°, and by providing steel flights inclines up to 30° may be negotiated at reduced capacity.

The constructional details of such devices need not be entered into here; such machines are generally of standardised design.

Heavy Type Band and Slat Conveyors, Etc., under this heading, are used in an entirely different way from the light or portable devices on the same principle (dealt with later and which rest on the quay); they are more often placed with one of their terminals upon the deck of the ship to be unloaded and with the other upon a delivery point which may be on an upper floor of a warehouse or upon a raised platform upon the quay; they may also be used between two vessels. In most cases these conveyors cover a long span high above the quay; it is therefore necessary that the conveyor proper should be housed in a very substantial framing, generally of timber and suitably trussed. The conveyors used may be of the endless band type, or of the same type but with wooden slats across at regular distances apart; or they may be of the chain type in which two endless chains travel between the terminals with wooden or steel slats to connect them, at a pitch of 12 in. or more; or they may be endless articulated steel bands, known as apron conveyors, which latter type is more particularly used for loading and unloading miscellaneous cargo in the United States.

In some cases there is a sufficient incline available between the terminals, so that a mere shoot will answer the purpose for unloading by gravity. Conveyors of this heavy class may handle cargo *ex* ship in a horizontal direction as well as on a rising or down gradient, as may be necessary, according to the freeboard of the vessel. A slat conveyor has a rather more universal application and is for more variable inclines, since the slats prevent the objects from sliding back on an uphill gradient, and on a downhill gradient from gaining speed beyond that of the conveyor. A plain gravity shoot cannot be employed on a steep gradient without running the risk of damaging the objects through impact after a quick descent.

Portable Handling Devices on Road Wheels may be divided into devices for two distinct functions: one for transporting freight from one place to another upon the ground level; the other for stowing the goods away on top of each other in order to occupy a minimum of space, these latter devices being known as stackers; both operations are necessary whether manual or mechanical methods are employed. And lastly, devices of this class are those which really merit the term "*portable*," being as light in weight as is consistent with strength.

Fig. 946. Hepburn Conveyor Employed in Emptying Brick Kilns.

The Simon Portable Unit Conveyor consists of a slat type machine, usually 24 to 32 in. wide, composed of two matched strands of endless running chain in which every alternate link is provided with a hard wood slat, the intervening links being fitted with steel cross bars, the ends of which are fitted with rollers running on angle iron paths which form part of a neat steel structural frame, the sides of which are latticed. The terminals are composed of substantial steel spindles fitted with two sprockets for the two chains, which spindles project at both ends and carry two smaller sprockets, by means of which they can be coupled up to the next unit by short driving chains. The standard lengths of these units are 9 to 60 ft., from centre to centre. They are interchangeable and mounted on ball-bearing castors so that they can be easily moved from place to place. Driving power is provided to one or more of the units of any lay-out, according to its length. Such power-driven sections are fitted either with electro-motors, or where no current is available, gasoline engines are applied. Whatever the source of power, it is first transmitted to the section to which the motor is attached, and a further unit can be driven from each end, and these in turn can be coupled on to others.

Armour-Plated Band Conveyors are used for handling bricks out of kilns to motor lorries, carts, or railway trucks, and Fig. 946 shows one thus employed. This

conveyor is portable on fair-sized road wheels; its height is adjusted by means of four hand wheels, and two adjustable stanchions, one at either end, keep the conveyor steady. These latter supports are not really necessary, but as the conveyor is kept in the same position for some considerable time while each kiln is being emptied, it was thought quite worth while to fix them well in position, and thus protect them against accidental displacement.

The endless belt is of solid woven bituminous cotton canvas, and the armour plating

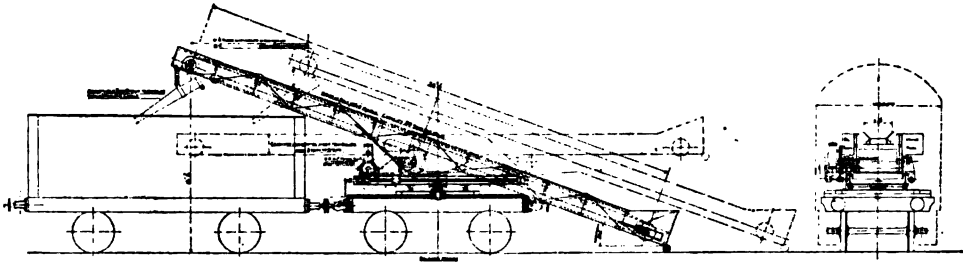


Fig. 947. Hepburn Portable Conveyor on Rail Track.

is introduced to protect the belt from the cutting effect of the bricks. The steel strips are heavily japped and fastened to the belt by two or three pronged fasteners clinched over on the under side.

Before the introduction of these conveyors the average cost of loading bricks into carts by hand was 1s. per thousand. Only one vehicle could be loaded at a time by two men, and this took on an average one hour. With the conveyor in operation the same

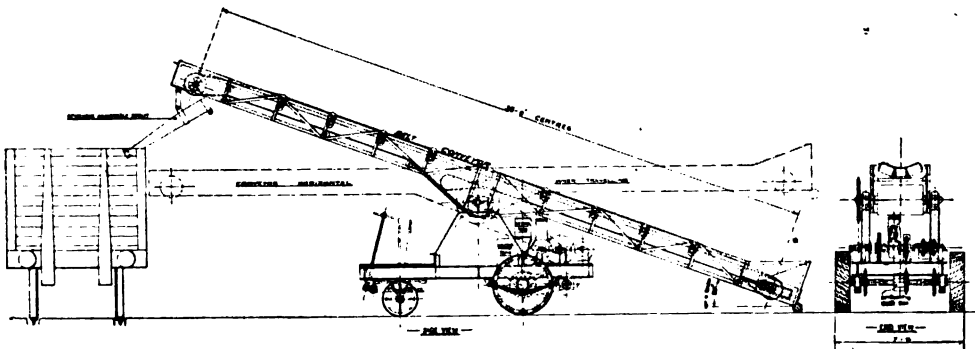


Fig. 948. Hepburn Conveyor Mounted on a Motor Lorry.

two men load in one hour three motor lorries, equal to the work of six men formerly, and the cost of loading a thousand bricks is now a trifle over 4d.

A similar conveyor is shown in Fig. 947. It is suitably mounted on a lattice frame hinged to fixings on an ordinary bolster wagon, and arranged with a sliding base and composite petrol motor-driven gearing. It is used in connection with railways, gasworks, quarries, and in any place where stacks of bulk material have to be formed and reclaimed.

The device shown in Fig. 948 is again similar, but instead of running on a railway track it is fitted on a motor lorry base and broad traction wheels for use on soft ground. These conveyors are by The Hepburn Conveyor Co., Ltd., Wakefield.

The Mitchell Stacker and Loader, built by Fraser & Chalmers, Ltd., is a simple machine that can be handled by the roughest unskilled labour, and which requires very little power. It consists of an ordinary belt conveyor, mounted in such a way that it can be extended in either direction, turned on a pivot to any position in plan, racked to any angle of inclination, and wheeled along to any position required. The telescopic movement is performed by a rack and pinion, the changing of the inclination by a similar device, while a man can easily revolve the machine by hand about the centre pin, or wheel the whole along the track. The driving power is furnished by a small steam engine, an

Fig. 949. The Mitchell Stacker Employed as an Unloader.

electro-motor, or by an oil engine. These loaders are made for capacities up to 200 tons per hour, and will take any size material.

The machine, as shown in Fig. 949, is used as an unloader. The receiving hopper is placed close to the door of the truck to be discharged, and the delivery end extended

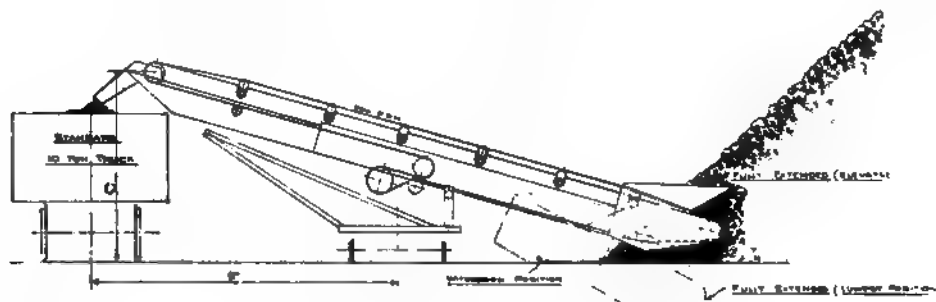


Fig. 950. The Mitchell Stacker Employed as a Loader.

as required. The material to be stacked is then raked from the truck into the hopper, from which it is conveyed to the heap by the belt. Several rail tracks can be placed parallel to one another at regular intervals if a larger storage area has to be filled.

The same machine, as a loader, is shown in Fig. 950, for replacing the material into the trucks. It is simply turned round and the hopper allowed to bear against the heap. The material above the level of the hopper is then raked down into it, and all below (about 2 ft.) shovelled into it. As the heap recedes the conveyor extends automatically by its own weight, so that the hopper is always kept tight against the heap. The only material that has to be shovelled is that actually below the hopper level, and the work on

this comparatively small quantity is identical with the filling of baskets in the old method without, however, all the carrying and lifting.

Similar conveyors are built (see Fig. 951) for taking passengers' luggage from the wharf and discharging it on the decks of large Atlantic liners. The baggage is placed on an endless belt 4 ft. 3 in. wide, fitted with wooden slats, which prevent any possibility of the articles slipping backward when the ship is high out of the water and the

Fig. 951. Spencer's Luggage Conveyor.

conveyor working at a steep incline. The machine is driven by an electro-motor through suitable gearing at the side of the conveyor. It is mounted on a pair of large diameter road wheels at about the centre of its length, and it is also fitted with a pair of smaller wheels at either extremity. The overall length of the conveyor is 53 ft. The apparatus is reversible so that baggage can be discharged from the ship on to the quay. Similar baggage conveyors are made telescopic, so that they can be shortened when not in use, and their movement on the quay thereby facilitated. They are only 30 ft.

long in the closed position, and can thus be utilised for all distances between 30 and 50 ft. The makers of these machines are Spencer & Co., Ltd., of Melksham.

Spencer's Stacking Machine.—Several units of a sack conveyor, terminating in a sack stacking machine, are shown in Fig. 952. The stacker is in its lowest position, and can be raised to a considerable angle as the stack increases in height. This is also made by the same engineers as the one last illustrated.

Stacking Device for Shell Boxes.—Such a device is illustrated in Fig. 953. It is of the gravity roller type, with the application of a power-driven chain for hauling the cases up to the discharge at the top. Other features shown on the drawing are the

Fig. 952. Portable Band Conveyor Handling Sacks.

hinging of the conveyor, so arranged that it can be placed at any angle at any height from the floor of the pivot. Driving power is supplied by a 3 H.P. electro-motor.

Simon's Stacking Machine.—This device was largely employed during the war for accumulating sacks of forage for stacking. The angle at which the bales are elevated is adjusted from time to time to the height of the growing stack, and with every succeeding tier the incline becomes steeper. A number of machines in different positions are generally used for forming big stacks, otherwise the position of a single machine must be frequently altered in order that the men on top should not have a lot of lifting and lugging to perform. Bags of sugar have been piled to a height of 25 ft. at the rate of from 500 to 1,600 bags per hour, by the aid of such a machine, and with only six men in attendance, whereas formerly it took thirty men to do the same work.

Rownson, Drew, & Clydesdale's Stacking Machine.—A similar stacker is

illustrated in Fig. 954; it is composed of a slat conveyor, and is for handling cases. It consists of two endless chains carrying steel or wooden slats 18 or 24 in. wide, which skid in angle guides braced together to form the framework of the machine. The maximum incline is 45°; small cleats are attached to the slats at intervals to prevent packages from sliding backwards. The upper portion, or jib, is hinged to give a range of stacking heights, with a minimum of 4 ft. and a maximum of 15 to 20 ft., or any height for which

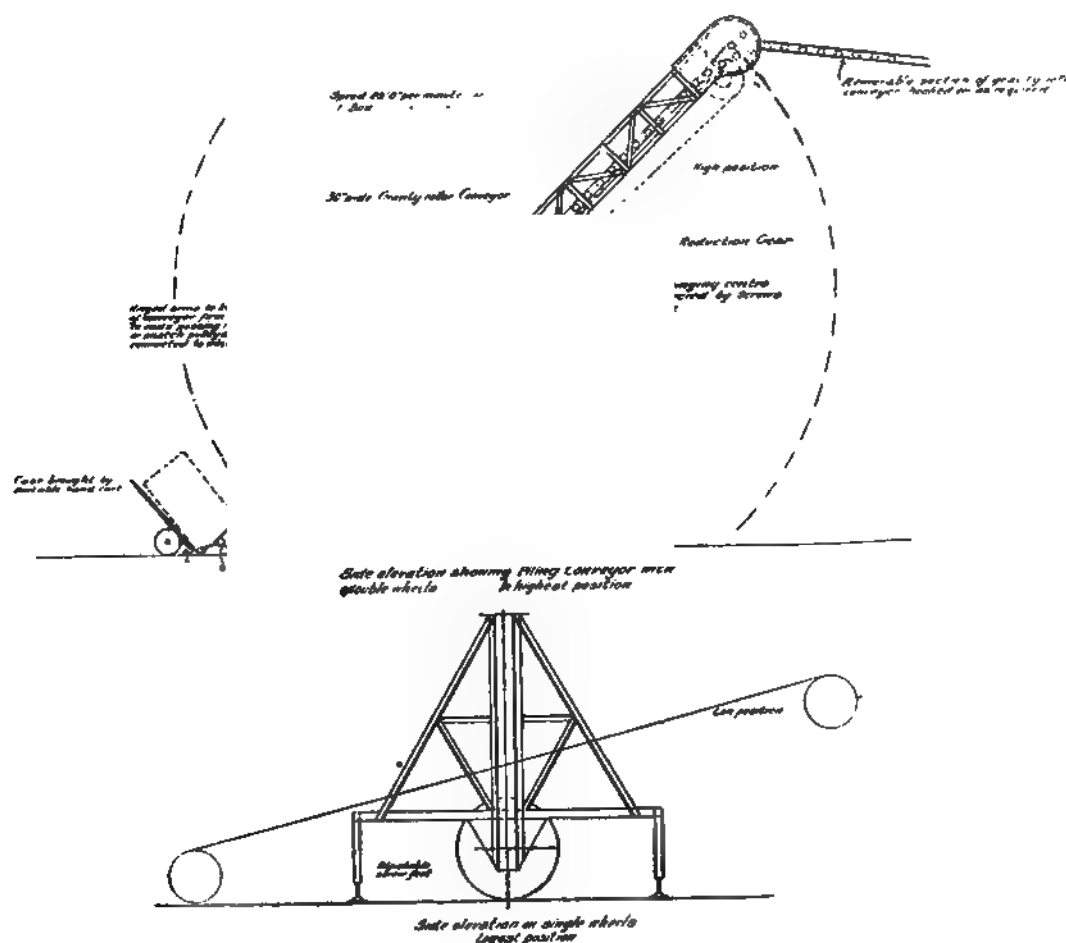


Fig. 953. Portable Device for Stacking Shell Cases.

the machine is designed. The usual speed of the chain is 60 ft. per minute, and the capacity 100 packages per hour. A $2\frac{1}{2}$ to 3 H.P. electro-motor usually supplies the motive power.

The Portable Bucket Elevator is an appliance for unloading bulk material. It is executed in a variety of designs differing, but little in outward appearance, but embodying attributes which make them applicable to all kinds of loading, from off the ground to anywhere within their reach. When the first machines were designed they were intended for handling anthracite coal, but they are now made to handle small bituminous

coal, sand, gravel, fine cement, etc. They can be moved by one or two men, according to the condition of the ground, and if it is desirable to load or unload some distance off, the loader can be hitched to a wagon and hauled to the scene of action. These loaders

Fig. 934. Rownson, Drew, & Clydesdale's Stacking Machine.

are made with and without feed attachment, the use of which is of considerable advantage, as this device pulls the material to the elevator buckets and dispenses with human labour for pushing the material down the pile into the machine. The feeder conveyor can be raised and lowered by cable and hand winch; the cable runs through telescopic pipes

Fig. 955. General Arrangement of Portable Bucket Elevator.

which protect it from becoming entangled with the running machinery; a shaker screen can be provided by means of which the coal, etc., can be sifted before loading. Some of these appliances are self-propelling, when they require only one man to operate them

Fig. 956. Bulk Loader of the Jackson Manufacturing Co.

except when raising or lowering, when two men are necessary. They are built for capacities of from 40 to 60 tons per hour. An attachment may also be had for bagging the material, particularly coal. By raising a hinged plate at the end of the shaking screen the coal can be made to drop into a bag hopper after having been screened. The sacks are attached to the discharge spout and are filled by opening a valve, or a shoot can be provided which extends to one side of the machine so that the sacks can rest on the ground while being filled.

With the previous descriptions of similar machines the accompanying illustrations need next to no further explanation. Fig. 955 represents the general arrangement of the type of

Fig. 957. Jeffrey Loader Handling Sand.

the machines. Fig. 958 shows a somewhat similar type which, however, gives a better delivery. Here a steel frame carries an endless chain of buckets which pick the material

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Fig. 958. Jeffrey Loader Handling Crushed Stone.

Fig. 959. Jeffrey Loader Handling Anthracite Coal.

off the ground, and discharge it at the top into a bin and spout. The frame is mounted upon a pair of "caterpillars," each of which has its own motor, the machine being turned

and steered by varying the speeds independently. It can feed itself against the pile of coal, stone, or gravel, and move about the yard at a speed of 75 ft. per minute; its weight is a little under 3 tons. The twenty-five buckets have a capacity of 1 yd., and discharge at the rate of thirty per minute, so that fully 1 cub. yd. per minute is delivered. The bucket chain is driven by a steel link belt, which passes over a motor-driven drum on the frame and over a sprocket on the bucket shaft at the head of the ladder. Motors of 5 H.P. are used.

A motor-driven loader of the Jeffrey Manufacturing Co., handling sand at the rate of 1 cub. yd. per minute, is shown in photographic view, Fig. 957—note the serrated edges of the buckets. In Fig. 958 is shown a loader driven by a gasoline engine, handling crushed stone from a storage pile to a railway truck. Fig. 959 is a loader handling anthracite coal, and screening it at the same time.

Figs. 960 and 961. Portable Loading Device for Salt.
(The dimensions are in millimetres.)

These loaders can be most successfully used for handling fertilisers, practically all shovellers being eliminated thereby, while the number of wheelbarrows and carmen is reduced, as they do not have to wait for their loads. When operating on a pile of hard complete fertiliser, a loader will dig itself in automatically until the material thus undercut breaks loose from above, and sometimes even buries the lower end of the machine; but such a caving-in will in no way interfere with the handling, and in case of a jam the clutches will slip and prevent breakage.

When loading soft goods no pickers are necessary on the pile as the material will likewise slide down to the loading point. All shovelling, with the exception of that of one man, can be dispensed with, and he is only employed to clear away under the wheels of the machine as she moves into the pile.

Portable Loading Device for Salt, by Fredenhagen.¹—This particular

¹ The facts and the illustrations are taken from an article by Hub. Hermanns in the *Zeitschrift des Vereines deutscher Ingenieure*, of 5th June 1913.

machine is designed for loading salt from a heap into trucks which are placed beneath the discharge shoot. The diagrams (Figs. 960 and 961) show that the platform of the truck is provided with four pairs of wheels, so placed that the whole machine may be reversed on the rails. The two pairs of wheels shown on the track can be raised by screw tackle and worm, and worm wheels, each pair of wheels being coupled to move simultaneously; and the effect of raising one set of wheels is equivalent to bringing the other four (which stand at right angles to them) down. The whole machine is then lifted by hand and turned 90°, if more convenient in that position for loading.

The elevator, which constitutes the principal portion of the device, is driven at the lower terminal by a belt and worm gear from an electric motor, and the elevator well is widened so that the material can be easily shovelled in. This would practically complete

Figs. 962 and 963. Portable Loader for Dusty Material.

(The dimensions are in millimetres.)

the machine for many purposes, but in this particular case, the installation being for handling salt, a short worm conveyor is inserted between the delivery from the elevator to the truck, presumably to break up any conglomeration of the salt. The worm so used is driven by a separate belt from the motor.

Portable Loader for Dusty Material.—A similar plant by the same firm is depicted in Figs. 962 and 963 for handling dusty material. As the method of reversing the machine on the rails previously described must be looked upon as rather a primitive way of doing things, the present machine is so built that the whole upper part can be rotated on a turntable running on a ball race. The incline of the elevator is alterable, and as the well is open at the circumference (protected by bars as usual), it can be pushed into the heap to be removed when it will feed itself. The elevator is raised or lowered by a small winch driven by hand, and the delivery shoot is made with a universal joint and telescoped. The final delivery into the tipping trucks is through a shoot, which is

connected to the centre of the lid fitting the truck, to prevent dust escaping. The electro-motor is geared by three countershafts and chains to the upper terminal of the

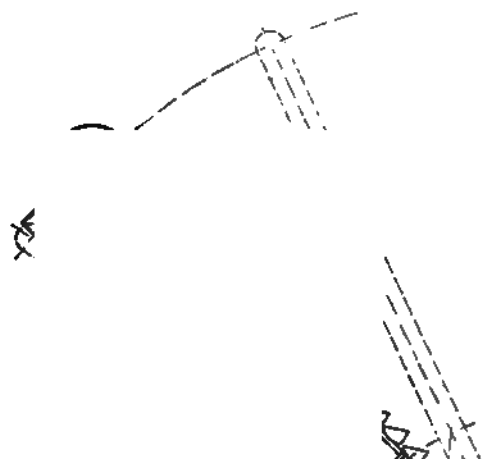


Fig. 964. Portable Loading Elevator Fed by a Portable Band Conveyor.

elevator, and the lower one is fitted with a tightening gear. The speed of the elevator is 120 ft. per minute, and the capacity, when handling minerals, up to 30 tons per hour.

Figs. 965 and 966. Portable Apparatus for Raising Acetylene Slurry.
(The dimensions are in millimetres.)

A somewhat similar machine, but applicable to all sorts of material, is shown in Fig. 964, but unlike the previous one, where the elevator head was in a fixed position, the order is here reversed, and the lower terminal is a fixture. The carriage of this machine is fitted with ordinary road wheels, and is therefore independent of rails. A frequent

method of using this device is by feeding it with one or more self-contained and portable band conveyors, one of which is shown in the diagram. The drive is geared to the lower terminal of the elevator, and the extreme positions of the latter are shown in dotted lines.

A Special Appliance for Raising Acetylene Slurry from a pit into trucks is shown in Figs. 965 and 966, and is also the design of Fredenhagen. The pits are of a smooth finish inside, being rendered with cement, and into this the lower or receiving

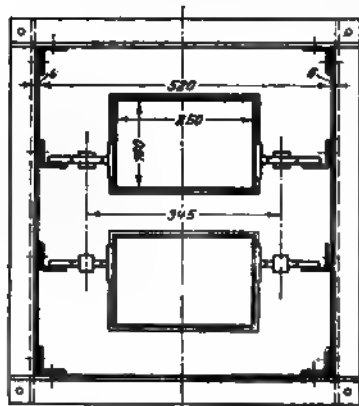


Fig. 967. Cross Section of Elevator shown in Figs. 965 and 966.

end of the elevator dips, the driving gear and the remainder of the gearing being carried on a portable platform on rails. The elevator is enclosed, and Fig. 967 shows a cross section. The casing tapers getting wider at the lower terminal, the elevator chains are depressed at the delivery point by two jockey pulleys for better delivery, the material being of a somewhat sticky nature. Fig. 968 shows one of the buckets which, instead of the usual skidder bar, has a projection on the carrying link which answers the same purpose. The buckets are 24 in. pitch, and the upper terminal is 24 in. and the lower 16 in. in diameter. The swinging support of the elevator is shown in Fig. 969. The two main

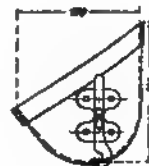


Fig. 968. Detail of Elevator Bucket.

bearings A A are secured to the framing of the carriage. They support a hollow spindle B, and keyed upon this are the two flanges C C, which carry the elevator; also keyed to the spindle is the segment of a worm wheel E, which controls the inclined position of the elevator. The driving spindle passes through the hollow one and is geared, as shown, on to the upper terminal. The incline is altered by a hand lever and a ratchet on the worm spindle.

Portable Devices for Handling Coke in Gasworks.—For handling coke from the heaps in the yards of gasworks, many simple and useful appliances are made. They are often fitted with a short reciprocating or revolving sieve to separate the breeze, and also occasionally with a coke breaker.

Figs. 970 and 971 show the outline of such a machine by Stotz. The carriage is on ordinary cast-iron wheels, and therefore independent of rails, and can be moved to any spot in a level yard within reach of the electric mains. The coke is shovelled into the hopper extension of the elevator well, which has a bar screen to prevent pieces too large from entering. The motor, geared to the elevator and screen, also gives motion to the carriage when necessary. The rest of the arrangement is sufficiently clear from the diagram. These appliances are generally used for retailing coke from gasworks.

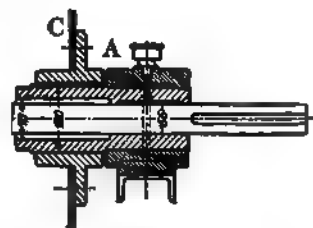


Fig. 969. Pivoted Support of Elevator shown in Figs. 965 and 966.

Portable Devices for Loading Potash and Other Salts into Railway

Trucks.—Such appliances may be used for all materials in bulk which are to be loaded into box trucks, and are exceedingly useful labour savers, and very inexpensive in first cost; they consist of a large oblique tapered shoot which terminates into a worm conveyor *l*,

Figs. 970 and 971. Portable Coke-Handling Plant.

Fig. 972. The worm is driven by an electro-motor fixed to the back end of the worm casing, and moves, therefore, with the worm. The movements are in both horizontal and vertical direction, so that all parts of the railway truck may be reached sufficiently to fill

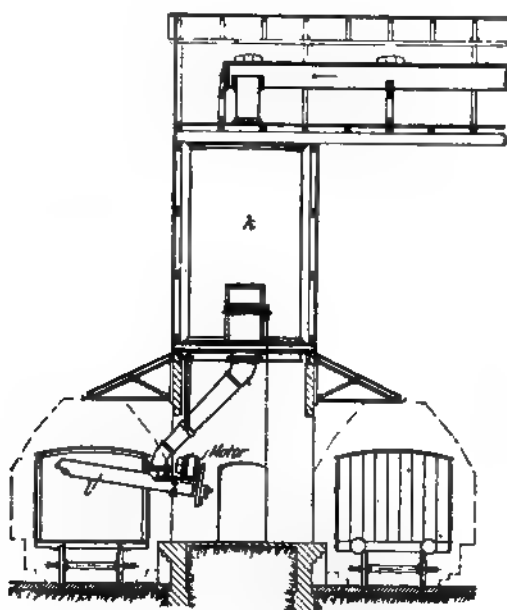


Fig. 972. Device for Loading Salt into Closed Railway Trucks.

the truck without any hand labour. A 10-ton truck can be filled by such a device in seven to eight minutes. The salt is conveyed by a worm to hopper *A*, from which it is admitted to the loader by an inlet valve.

Vertical Stackers.—Where goods in cases, bales, and similar articles have to be stacked vertically, instead of up an incline, as is the case where either the space is

confined or the weight of the articles dealt with is too great for the continuous devices, a vertical elevator is recommended in preference. There are many varieties of these machines in use, but descriptions of two of the latest types only will be given here.

Spencer's Vertical Elevator (Fig. 973).—The height of this machine is about 23 ft. over all, but it is built to suit warehouses of any height. The motor which drives the elevator is reversible, so that the same apparatus can equally well be used for forming the stack and for removing the packages from it. Hinged tables or platforms are provided, which are used in the following manner: By means of a hand winch one of the tables is adjusted to the same level as that of the existing stack, or thereabouts: the motor is then started, and the elevator ascends at the side remote from that on which the platform has been adjusted. Packages placed on the receptacle on that side of the elevator will now ascend, negotiate the upper terminal and descend on the other side until the platform is reached, when the receptacle continues on its downward path, leaving the packages on the platform, where a man receives them and transfers them to the stack. To disperse the stack the arrangements are slightly modified: the motor is reversed, *i.e.*, runs in the opposite direction, and if packages are now removed from the stack and placed upon the platform, one of the now ascending receptacles will lift them from the platform, ascend over the upper terminal of the elevator, and descend on the other side until impeded by

Fig. 973. Spencer's Vertical Stacking Elevator for Packages other than Sacks.

a similar platform which will arrest the packages, while the receptacle proceeds on its endless journey round and round.

Woodfield's Electro-Stacker.—This device is shown in Fig. 974. It consists of a hinged or telescoped mild steel structure mounted on a carriage, which can be provided with a ball-bearing turntable. Provision for lowering the machines is necessary in order that they may be wheeled through doorways of lesser height than the height of lift of the

platform. This also enables the machine to operate in the old as well as in the new warehouses. The under-carriage is fitted with broad road wheels with ball or roller bearings, the wheel or wheels being of the swivel castor type to enable the machine to turn on its own axis. The electro-motor is housed in the lowest part of the steel structure, and from this the hoist is manipulated by a chain drive and gearing. The winding drum raises the platform upon which the load is placed; lowering is effected by gravity under perfect control by a band brake. The hoisting is performed by a band clutch and gear. The lightest pressure on the operating lever puts the band clutch into engagement, and the load is hoisted. When it has reached the required height the lever is allowed to fall, and its own weight is sufficient to sustain the load with the band brake, which is fixed on the same shaft to the elevating clutch. Lowering is accomplished free barrel by slightly raising the lever, so is midway between the hoisting and brake.

The whole operation of loading, hoisting a load of 10 cwt. is accomplished at an average of 30 sec. This is naturally governed by the height which varies from 3 to 25 ft. Loads of from 3 to 25 cwt. can be stacked. The lifting platform is open and unencumbered on three sides. Machines of smaller size are fitted with tipping platforms to relieve manual strain. This machine is manufactured by the Wellman Smith Owen Engineering Corporation, Ltd., of London and Darlaston.

Larger Portable Handling Devices.

—Before concluding this chapter, mention must be made of two devices which, though portable, are of such weight and dimensions that it is necessary to place them into their temporary positions for use by either quay cranes or by the ship's derricks. These devices are: the Donald elevator conveyor, and the Michener elevator for coaling vessels.

The Donald Elevator Conveyor.—

As its name implies, this device is a combined elevator and conveyor. It is designed for the specific purpose of loading in and out of ships of cargo of more or less uniform nature, in units, the weight of which should not exceed 2 cwt. The machine successfully handles such cargoes as frozen mutton, bananas (crated and uncrated), barrels, cased and bagged stuff, cheese, drain pipes, etc., within the limits of the above weight.

The machine proper (see Figs. 975, 976, and 977) consists of a light structural steel frame, arranged to rest with one end on the hatch coaming and with the other on the bulwark of the ship. The steel framework carries a series of rollers and gearing which support and operate the two endless chains carrying the canvas slings between them in which the cargo is handled. The canvas slings are secured by stout jute loops to

Fig. 974. Woodfield's Vertical Electro-Stacker.

Figs. 976, 978, and 977.

steel tube cross-bars, connecting the two chains. The size of the canvas slings depends upon the cargo to be handled; thus for carcasses of mutton the slings would be 4 ft. wide, and the two chains 5 ft. to 5 ft. 6 in. apart; one might say, however, that a 4-ft. sling will carry most cargoes. The speed at which the chain travels is 60 ft. to 100 ft. per minute, and the pitch of the canvas slings varies from 2 ft. 6 in. to 3 ft. 4 in., giving capacities of from 600 to 2,400 packages per hour, according to the weight of the goods handled.

The conveyor is placed upon the ship in such a way that the receiving terminal plumbs the hold, and the other terminal extends over the side of the vessel, reaching either to the quay or barge alongside, wherever cargo is to be dumped. To overcome any differences occasioned by alteration of water level or cargo working, a supplementary gear is provided which is controlled by a small hand winch. This supplementary gear alters the length of either the feeding or discharging bight, as required.

For driving purposes a 3 H.P. electro-motor is usually sufficient, the power being taken from ship's supply or from adjacent warehouses. Failing electric supply, petrol motors have been successfully used.

The average weight of the machine as described is from 2 to 2½ tons complete, a weight which can be handled by most ships' derricks.

The same principle applies to travelling quay conveyors of the cantilever warehouse type, in which the framework of the machine is carried on the warehouse wall and is made to slew round against the wall when not in use. The makers of these machines are Rownson, Drew, & Clydesdale, of London and New York.

The "Michener" Elevator for Coaling Vessels.—The "Michener" elevator is manufactured by the Wellman Smith Owen Engineering Corporation, Ltd., King's House, Kingsway, London.

A side elevation of one of these elevators, showing the receiving terminal at its highest point, is shown in Fig. 978. In the other extreme the same terminal is lowered 23 ft.

It will be seen from the drawing that the receiving terminal revolves in the opposite direction to that usual in elevators; it is therefore what is termed underfed. After a vertical run, beginning at the lower terminal, the chain of buckets negotiates the guide idler *c*, and assumes an essentially horizontal direction towards the power-driven sprocket *e*, and the coal leaves the buckets during this short run, dropping into a slightly hopped receptacle which terminates in a bifurcated shoot which in turn leads, via telescopic shoots, into the port mouth. The coal may be directed by means of a gate into either of the two shoots, or split up between both. In the case of a particularly high port, where there would not be sufficient fall to reach two ports, the delivery of the whole of the coal is made into one. We see from the foregoing that as a rule the greater part of the chain of buckets is not loaded with coal.

The stationary part of the device is called the head, while the other part, which adjusts itself to the cargo level, is called the leg.

The Head Gear, which is the most important part of the machine, has the external appearance of a V-shaped steel structure with an upward extension which guides and supports the elevator leg. A 10 H.P. electro-motor provides driving power for the elevator; its spindle is marked *a*. The motor is geared by a silent chain drive to the first countershaft *b*, which in turn is geared to spindles *c* and *d* by spur wheels to the driven terminal sprocket *e*, which actuates the whole elevator. The sprocket



Fig. 978. Side Elevation of Coal Elevator in its Highest Position.

wheels F, G, H, and I are merely idlers which guide the chain of buckets in their prescribed path. A hoisting drum which raises the elevator leg relative to the head gear is shown in K; it is driven by a silent chain gear from the elevator spindle E. When the elevator is at work the hoisting drum is stationary, since a spur wheel and pawl will permit the sprocket to revolve idly; but immediately the motor is reversed the drum is in gear. A $\frac{5}{8}$ -in. steel wire rope is wound two or three times round the drum, and the two ends of the rope are fastened respectively to the upper and lower end of the elevator leg. Thus the slow revolution of the drum will raise the leg out of the barge. When the raising is in progress the elevator chain runs backward so that the buckets empty themselves. The leg is lowered into the barge in a similar way, but more under the influence of gravity. There is a device on the head gear which prevents the lower terminal of the elevator from digging itself too deeply into the coal, and which does not allow the lowering of the leg more than 2 ft. at a time.

The Elevator Leg slides vertically through the head gear, and is raised and lowered by the drum as may be necessary. The leg consists of two identical endless chains and sixty-three buckets; these are 1 ft. $8\frac{1}{2}$ in. wide in front view, 11 in. high and 10 in. deep. The return strand of the elevator chain is enclosed by a sheet steel trunk, and the loaded strand by a telescopic shoot. In Fig. 978 this telescopic shoot is closed up, and thus limits the uppermost position of the leg. Enclosing the chain by steel shoots prevents accidents, also the dropping down of lumps of coal upon the heads of the men in the barge who may be engaged in trimming.

The average capacity of each coaling elevator is reckoned at 125 tons of coal per hour, but the actual capacity varies according to the amount of coal in the barge, and also according to the rate at which it can be trimmed in the bunkers of the vessel. The time occupied in changing full barges for empty ones enters also into the calculation for the average capacity. From a full barge under favourable conditions the elevator can raise coal at the rate of 200 tons per hour. The device is about $5\frac{1}{2}$ tons in weight.

With regard to the advantage of this coaling device over hand labour, as each elevator feeds two coal shoots it is doing the work of sixteen men formerly employed.

Method of Coaling.—When a ship has to be coaled the elevators are placed in position by a crane on the wharf or boom from the ship, or from a floating derrick alongside. Four elevators in use are shown in Fig. 979. The two rollers which form part of the head gear protect the ship's side, while the elevator is adjusted to the height of the coal ports. The elevators are suspended by the head from the ship's side at any desired position by tackle attached to the deck or other available point of the ship. After the elevator is placed in working position all pier and floating equipment is released.

After attaching the elevator to the vessel the leg is raised sufficiently to allow a barge to be moored alongside, below the elevator, which is then lowered into the coal. At the same time spout connection is established between the delivery shoot of the

Fig. 979. Four "Michener" Elevators Coaling the U.S.S. "George Washington," an ex-German Liner.

elevator and one or two of the coal ports. As the leg is lowered into the barge the chain of buckets starts to operate, and the speed at which the leg descends is governed by the speed of the motor. Under normal conditions this is gradual and automatic, so that as it reaches the coal the buckets fill and elevate. The lowering of the leg is governed by a ratchet wheel and pawl on the drum spindle, which control the leg while lowering, allowing the ratchet to run ahead of the pawl when the leg reaches the coal. While the weight of the leg influences the digging, it is so constructed that it will withdraw automatically if it should become choked.

Coal is delivered at a point determined by the position of the head, which is slung just high enough above the coal port into which delivery is to be made, allowing for the angle of the telescopic shoot at which the coal will just run freely and by gravity.

Some of the leading features and advantages of the elevator are its automaticity, the fact of its being self-contained, electrically driven, and controlled, and that each

unit is handled by one man only; and it can be used on the off-shore side as well as on the near side, or on both.

The off-shore coaling eliminates breasting the ship off from the wharf, and does not in any way interfere with the cargo handling between wharf and vessel.

The Michener bunker trimmer mechanism is designed for, and may with advantage be used in conjunction with the elevator. It keeps the intake port free from congestion in order that the elevator may have full scope and undiminished capacity. For other devices for coaling ships, see Chapter XXXIII., Section B.

MISCELLANEOUS INSTALLATIONS

CHAPTER XXXIX

THE COALING OF RAILWAY ENGINES

THIS country has been somewhat behind others, so far as such mechanical appliances are concerned, and they have only gradually been introduced. The old methods are still in evidence, baskets or other receptacles, holding about 1 cwt. of coal, being carried, often by hand, from the platform in the coal yard to the tender of the engine; small cranes worked by hand or by motive power are still employed for coaling locomotives—a most

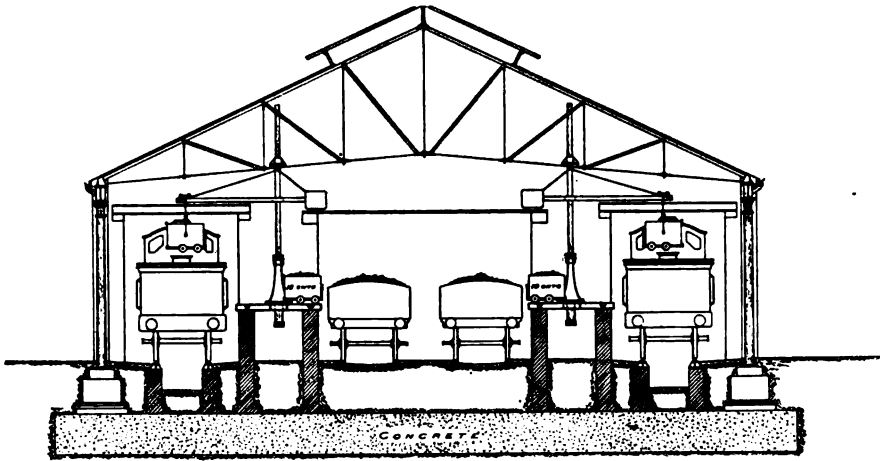


Fig. 980. Section of Old Coaling Stage at Crewe North Shed.

expensive proceeding. It pays to install mechanical equipment if 100 to 150 locomotives have to be coaled per day.

Old Coaling Stage at Crewe.¹—The old coaling stage at Crewe consisted of two decks, on each of which was placed three hydraulic cranes of 1 ton capacity (see Fig. 980). Between these decks were two sets of rails on which the full coal wagons stood, and on the other sides of the decks from the coal wagons were the roads on which the locomotives stood for coaling. The wagon and engine roads were on the same level, and the top of the deck about level with the bottom of the wagon. The men had therefore to dig down into the coal, lift it over the side of the wagon, and deposit it into boxes of 10 cwt. capacity. These boxes or tubs were provided with castors, so that they could be pushed about the

¹ Extract from a paper read before the Institution of Civil Engineers by C. T. B. Cooke, M.I.C.E.

deck at will and brought within the radius of any one of three hydraulic cranes by which they were picked up for emptying the contents on to the tender.

The increasing consumption of coal at the Crewe depot, and other causes, made the cost of transferring the coal from wagon to tender work out at 3·69d. per ton. This high price, and the fact that the tonnage dealt with annually at this coaling stage was the largest on the London and North-Western system, were two of the principal factors leading to consideration of the adoption of a mechanical coaling plant, which is fully described later.

Improvements have been made in coaling methods at Swindon and other railway centres where the coal wagon is raised and side door wagons are used.

Coaling Railway Engines on the South-Eastern and Chatham Railway.

—Some improvements were carried out at Slades Green by Mr S. Wainwright, chief mechanical engineer of the South-Eastern and Chatham Railway. For coaling the

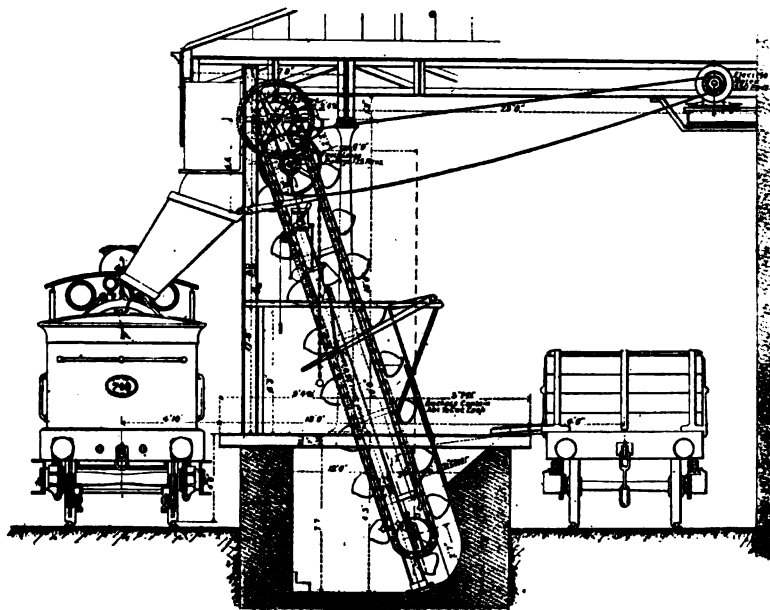


Fig. 981. Elevator for Coaling Railway Engines at Slades Green.

engines the coal stage is fitted, as shown in Fig. 981, with a bucket elevator which, after having undergone several modifications, has been given an extended trial with considerable success. The elevator consists of twenty buckets, each capable of containing about $\frac{1}{2}$ cwt. of coal loosely filled. These are secured to an endless chain which runs over two sprocket wheels, one mounted on the upper end of the frame under the roof of the stage, the other at the lower end in a pit some 7 ft. below the floor of the coal stage, into which pit the coal is shovelled direct from the wagons on the inside road.

An electro-motor is placed on a bracket on the engine-house wall about 20 ft. away; it makes about 500 revs. per minute, and drives (by means of covered-in belting) a countershaft on the elevator frame, while a pinion on this shaft gears into a large spur wheel, which drives the top terminal, the latter making about 25 revs. per minute. Working at this speed the buckets deliver coal down the shoot to the tender at the rate of about 1 ton per minute. To avoid jamming the buckets in the pit by an accumulation of coal, and so preventing the motor from starting, an automatic switch has been devised,

which, by the action of raising a slide and admitting coal into the pit, starts the motor before the slide is sufficiently raised to admit coal in any quantity, a water spray to lay the dust being simultaneously turned on. The coal is delivered close to the top of the tender, gear being provided to lift the shoot clear of the chimney and cab of the engine.¹

American Practice.—Extensive coaling installations have been erected in the United States for locomotives.² They are much larger than similar installations in Europe, as in America they have been able to centralise and make more economical arrangements, and also the country being new, the value of the land occupied by these installations is considerably less than in European countries, where the already existing arrangements often only admit of a limited space for the installation of such plant. Finally, the exceptionally high wages in the United States are a special incentive to mechanical equipments, for which reason comparatively few small installations are to be found.

The most universally adopted method of coaling railway engines consists of timber ramps constructed of trestle-work, up which the coal wagons are hauled by a locomotive; here the coal trucks, which are hopper-bottomed, are dumped into pockets, the outlets of which are sufficiently high above the ground for the coal to be shot direct by means of a shoot into the tenders. Such installations are extravagant for space, which would

Fig. 982. Cross Section through American Gravity Coaling Installation.

(The dimensions are in metres.)

probably not be generally available in this country. It is obvious that the greater the incline of these ramps the shorter will be their length. The most usual incline is one of 6 per cent., or 1 in 16·7, at which incline one locomotive can haul three 50-ton wagons. If the local conditions do not permit of the necessary space for such a ramp, and a steeper incline becomes necessary, the wagons are hauled up by a rope, which service is occasionally performed by locomotive. The inclines are then up to 20 per cent. and even more. The high level rails at the top of these ramps have frequently a slight downward gradient in the opposite direction, so that a wagon cannot accidentally run down. A further precaution against accidents is the use of safety switches. Fig. 982 shows a cross section through the highest portion of one of these devices, from which it will be seen that locomotives can be coaled at either side, and provision is also made for coal to be stored under the trestles. In one of the installations of the Pennsylvania Railway at Bergen Hill near Jersey City 150 locomotives are coaled daily. The advantage of this system of coaling over the more old-fashioned one used in America is that a reduction

¹ From *The Engineer*, 28rd May 1902.

² "Lokomotivstationen nordamerikanischer Eisenbahnen," by Dr Blum and E. Giese, *Zeitschrift des Vereines deutscher Ingenieure*, 8th Feb. 1908.

of hands from fourteen to five is effected, and the cost of loading coal into the tender of the engine is only a small fraction over $\frac{1}{2}$ d. per ton. This does not include the weighing of the coal, which is not feasible with this method of coaling; but in the old-fashioned method the cost was 6d. or 7d. per ton including weighing.

About the year 1907 coaling installations with gravity bucket conveyors (hereinafter called mechanical coaling appliances) were introduced and erected by Hunt, the Link Belt, and the Robin Belt Companies. They were at first received by railway companies with much enthusiasm, which was, however, checked later on account of the following defects:—

Firstly.—The finer mechanism of the gravity bucket conveyors is more subject to breakdowns under the rough treatment it might receive, and by coal getting into the driving gear through careless handling; a breakdown to the conveyor means a breakdown of the whole installation. Breakdowns have been known to cause stoppages which have lasted for fourteen days or over.

Secondly.—Objection is taken to the storage of large quantities of coal in enclosed receptacles on account of risk of spontaneous combustion, a risk intensified by oil dripping from the conveyor on to the coal.

Thirdly.—Such installations are only suitable for

Fig. 883. Coaling Plant for Railway Engines on the Philadelphia and Reading Railway, U.S.A.

comparatively small coal, and the large would therefore have to be broken, which diminishes its value.

Fourthly.—During frosty weather it has happened that the coal has frozen together and refused to leave the hoppers.

Fifthly.—The whole installation is of greater initial cost, which is only justified in the case of exceptionally large traffic, and the working and maintenance expenses are high.

Sixthly.—It is difficult to extend the capacity of such an installation should increased traffic render this necessary.

It might be mentioned that in spite of the above, such installations, fitted with mechanically equipped coaling appliances, are largely used where space is confined and where the creation of coal dust must be prevented.

To sum up, both systems are used; the local conditions generally determine which method is to be employed; and the ramp has not been superseded by the bucket elevator coaling station.

The mechanically equipped coaling devices are all of practically the same type, though some discharge the coal on one side only whilst others deliver to right and left, the largest ones serving as many as four lines of rails. They all receive the coal, by self-discharging hopper wagons, into a pit below the line (see Fig. 983), feeding into the gravity bucket conveyor. The structure is sometimes of iron, but more often of timber along the side of the lines for extending right across them, and having hinged shoots which lead from the lower ends of the hoppers to the tender. One or more such outlets are used which can be turned out of the way when not in use. There are generally a greater number of outlets, so that several locomotives can be coaled at once, and also because different sorts of coal are used, the railway companies generally using for ordinary purposes tender coal, which produces much smoke, because it is the cheapest. It is, however, unsuitable for express trains, and for this purpose harder coal has to be used. The overhead silos are, therefore, equally divided into two compartments, the larger one for soft and the smaller for hard coal. The installations are generally so arranged that the siding upon which the coal is brought in is not the same as that upon which the engines are coaled, so when an installation spans four lines of rails for coaling four engines at the same time one or two sidings on either side are used for the coal wagons.

An example of the above is the coaling plant for the railway engines of the Philadelphia and Reading Railway, United States of America. This extensive installation is illustrated in Fig. 983. Four locomotives can be simultaneously coaled and supplied with water and sand. There are two "Hunt" conveyors, one for coal and one for conveying the ashes from the engine to the receptacle provided for them. Between the coal and ash hoppers is a small hopper for sand which is shown in the illustration. The capacity of this plant is 600 tons of coal per day and five loads of ashes. Nearly 500 main-line and suburban locomotives call at this station every twenty-four hours. Similar installations are employed by the Boston and Albany, and other United States railways.

The staff employed consists of eleven men during the daytime, and one man during the night. The labour is divided as follows: One foreman, one stoker, one man in the coal tunnel, one in the ash tunnel, one man above for wetting ashes, four men for filling the tenders, and one for filling the locomotive water tanks. During the night-time one man in attendance sees to the loading of the locomotives with coal.

The desire to coal a greater number of engines has been the incentive to further developments whereby the engines are not fed direct from the elevated silo, but from a bridge spanning the railway which transfers the coal by small trucks on rails from the silos through small pockets and hinged shoots on to the tenders. This method has

the advantage that the coal can be weighed before delivery. Another great advantage is that the relative positions of the coal receptacle and the coaling siding are more or less immaterial, so that space of lesser value can be utilised for the erection of mechanically equipped coaling appliances.

The coaling installations being confined to the most important junctions, which are often great distances apart, it is necessary to provide locomotives with coal at intermediate stations. These auxiliary coaling facilities are not necessarily confined to the stations, but are sometimes erected on any convenient spot on the line; such installations are very similar to those previously described, but on a much smaller scale.

A different system again is that used on the Southern Pacific Railway, where the coal is stacked in a small heap, as shown in Fig. 984, and removed by a crane and grab to a portable hopper from which the engines can be coaled. The illustration explains itself, and it need only be mentioned that the hopper is portable in order that it may be adjusted as the one end of the pile becomes exhausted. It is said that the cost of transferring the coal in this way amounts to one penny per ton. This last installation is perhaps the starting-point for stocking larger quantities of coal, to which there is now

a greater tendency than ever in the United States. Formerly coal for not more than five or six days was kept in stock, and this was frequently stored in railway trucks and on sidings. The more modern method of storing it is in stock piles or heaps, which are described in Chapter XLI.

Coaling Station of the Munich Central Railway.—

This was erected by J. Pohlig, of Cologne, on American lines, Hunt's patent conveyor being used. The

Fig. 984. Coaling Installation as used on the Southern Pacific Railway.

(The dimensions are in metres.)

installation shown in Figs. 985 and 986 consists of a steel structure, which supports, in addition to four large coal hoppers, the necessary conveying machinery. The plant has been erected over a tunnel, through which the lower run of the Hunt conveyor travels. Above this tunnel is a coal hopper built of masonry, over which run three lines of rails. The coal is brought to this receptacle by self-emptying railway trucks, and can be withdrawn by a series of sixteen outlets on to the conveyor, which takes the coal to the top and delivers it to any one of the four hoppers, from which it can be withdrawn to fill the locomotive tenders on each side of the structure at a moment's notice. Thanks to the progressive example set principally by the London and North-Western Railway Co., we have now a goodly variety of locomotive coaling installations in this country.

Locomotive Coaling Installation of the London and North-Western Railway at Crewe.¹—The London and North-Western Railway Co. installed the first up-to-date coaling installation at their large locomotive running-sheds at Crewe. in 1912-13, and it is believed that by the introduction of this machinery the hitherto generally accepted British method of coaling by hand, or by devices necessitating considerable hand-shovelling, has for the first time been completely abandoned. By means of this plant the coal is removed automatically from the wagon, conveyed to and stored in overhead bunkers, measured and placed on the tender without spadework of

¹ Extract from a paper read before the Institution of Civil Engineers by Mr C. T. B. Cooke, M.I.C.E.

[To face page 676.]

any description. The plant was built by Babcock & Wilcox, and is the joint design of Mr Cooke and that firm.

It is desirable to describe shortly the conditions which existed before the advent of the mechanical apparatus, and also to say a few words generally on the question of handling coal mechanically for the use of locomotive engines.

It may be advisable to state here certain factors which have militated hitherto against the adoption of coaling machinery for locomotives in England, and also the reasons which led to the installation of the type of plant now described. The points to which careful consideration had to be given were :—

1. The cheap rate at which coal was then dealt with by hand.
2. The impossibility of obtaining reliable statistics of a plant suitable for British requirements.
3. The large size of coal mined in England.

Figs. 987 to 989. Coaling Installation of the London and North-Western Railway at Crewe.

4. The class and size of coal wagons in use.
5. The restricted area available in most steam-shed yards.
6. The regular and adequate supply of coal between colliery and steam-shed.
7. The high cost of land for extensions and alterations to yards.
8. The impracticability of one plant capable of dealing economically with coal between (i) wagon and tender ; (ii) wagon and stack ; and (iii) stack and wagon or tender.
9. The varied local conditions existing at steam-sheds on any one line.
10. The large outlay necessary for installing a plant, and the cost of working various plants.
11. The breakage of coal.

It is unnecessary to enlarge upon points Nos. 1 to 5, but as regards No. 6 it is found that, in those countries where long distances separate collieries from locomotive depots, it is absolutely necessary to keep large stocks of coal on hand, to carry over delays or stoppages ; such stacks really represent a combination of current and stock coal. They are, so to speak, continually on the move, and the conditions render it essential to

install mechanical means of readily taking up or putting down the coal, manual labour being out of the question from a commercial point of view.

The economical and commercial points have been dealt with fully in Mr Cooke's paper, and want of space forbids their mention here.

At the Crewe north steam-shed, at which about 130 engines are permanently stabled and about the same number are coaled daily, the quantity of coal transferred from truck to locomotive every twenty-four hours is about 450 tons, or 140,000 tons per annum.

The plant, which is shown in Figs. 987 to 990, consists of a wagon tipper, an underground hopper, a coal-breaker, a tipping tray conveyor, an elevated bunker, and shoots—including calibrating chambers—for discharging the coal on to the tenders.

As the coal wagons belonging to the railway company have neither side nor end doors, a "tippler" (on the principle of those used in collieries), capable of dealing with wagons of up to 10 tons capacity, became the initial part of the apparatus. An inclined

baffle plate fixed to the tippler rings, in conjunction with the fixed plate of the hopper, serves to retain the bulk of the coal in the wagon until it is nearly in its lowest position, and thus tends to minimise breakage—a very important point when dealing with the soft Welsh coal often used. The hopper holds about 20 tons, and is carried by cross girders in a brick-lined pit. The coal is fed from this hopper by a jiggling tray through an adjustable door—worked from ground level—into a two-roll breaker, where the large lumps are reduced to 8-in. cubes. This breaker is belt-driven by an independent direct current electric motor of 10 H.P., which also operates the jiggling tray. The coal passes, with the large lumps broken, to the conveyor trays, which carry it to the overhead storage.

Fig. 990. Cross Section through
Fig. 987.

Particular care has been taken to reduce the fall at all points to the minimum, and after passing through the breaker the coal slides a short distance on to the conveyor trays. Notwithstanding all precautions some breakage is bound to occur, especially when working with Welsh or soft coal; although, so far, there has been no apparent increase in coal consumption from this cause.

The conveyor is of the well-known Babcock-Wilcox "tipping tray" type, running at a speed of 70 ft. per minute and capable of lifting about 60 tons per hour. Adjustment is provided for at the bottom end, while the driving gear is situated at the top under the bunker housing, and consists of a 660-volt direct current electric motor of 9 H.P., driving through a belt and train of machine-cut gear wheels, the effect of which is to give a very quiet drive. All coal is delivered over the end of the conveyor track, but in order to prevent any breakage at this point a special form of balance plate retains it on the trays until the lowest point of the terminal pulley is reached, when it has a fall of only about 1 ft. on to the inclined shoot which delivers it to the requisite division of the bunker.

In approaching the design of the bunkers it was necessary to weigh carefully the

relative advantages of the large bunker against those of the small bunker, and in this case the balance was on the side of the former. The bunkers were therefore designed to hold 300 tons; this is more than enough to coal all engines during the night without the conveyor working, and it is thus possible to send up during the hours of daylight all the coal required, and to save double-manning the wagon tippler and conveyor.

Owing to a large number of main line engines being loaded with two classes of coal, namely, Welsh and "hard," it was necessary to provide separate storage for each class. The bunker is accordingly divided into two main parts, to store 100 tons of Welsh and 200 tons of "hard" coal. Working on the large bunker principle necessitates special arrangements to break the fall from the delivery shoot to the bottom of the bunker, when the latter is fairly empty in the mornings. This is done by special baffle plates in the case of the "hard" coal, and by spiral shoots in the case of the Welsh coal. The coal is thus delivered with a minimum of breakage, even when the bunkers are completely empty.

There is an outlet on each side of each division of the bunker, or four outlets in all, so that tenders can be coaled on both sides at the same time. The outlets in question measure 2 ft. by 2 ft., and are provided with undercut balanced doors, worked by hand, which up to the present have been very successful and free from "jams." By opening one of the doors coal is permitted to flow into a calibrating chamber formed in the shoot between bunker and tender. The bottom end of this chamber is closed by a door, worked by a lever conveniently situated, and it is so arranged that the contents of the calibrating chamber are equal to 10 cwt. On the upper door being shut and the lower door being opened, the 10 cwt. of coal is free to slide on to the tender. The shoots are built at an angle of 45° to the rail. The lower doors have adjustable hinges, which allows the capacity of the calibrating chamber to be varied until the best average is arrived at. It has been found possible to set these bottom doors so exactly that the difference between the calculated weight delivered to the tenders and the known weight sent up to the bunkers was only 4 tons 1 cwt. in a month's working, or about 1 ton per calibrating chamber per month. This method of obtaining the weight has therefore proved quite satisfactory; so also has the speed of coaling—as much as 6 tons being put on in three minutes, as against 5 tons in fifteen minutes with the old system under the most favourable circumstances. The average daily quantity of coal placed on tenders is now about 450 tons, and the new plant performs this task with a staff of three men by day and one by night, the conveyor being at work approximately ten hours per day.

At present between 140 and 150 engines are coaled per twenty-four hours, and the coal can be placed on the tenders at the rate of 2 tons per minute; these figures will show that, so far as speed of coaling is concerned, there is a large margin of time in reserve.

Under the new condition of things an engine coming off the turntable would proceed in the following way, and would be detained for the time stated for each process:—

Cleaning smoke-box of ashes	-	-	-	-	4	minutes
Filling tank at water column	-	-	-	-	3½	„
Cleaning tubes	-	-	-	-	4½	„
Coaling engine	-	-	-	-	4	„
Dropping fire	-	-	-	-	8	„
Total	-	-	-	-	24	minutes

These are the actual times taken by the several operations, and, as they are performed in places only a few feet apart, little additional time is occupied in moving from one place to another. Under the old conditions the time taken was one and a quarter to one and three-quarter hours.

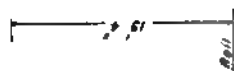
Locomotive Coaling Installation of the London and North-Western Railway at Camden Town.—Owing to the unqualified success of the installation at Crewe, it was followed, in 1914, by one at Camden Town, erected by Fraser & Chalmers. In this case the bunkers or silos were omitted owing to the want of space. It was, therefore, necessary to make the conveyor of such a capacity that the contents of twenty to twenty-five buckets were sufficient to charge a tender and to run the conveyor just for the short space of time necessary for this number of buckets to discharge. The coaling at this spot was previously manual, and the sheds provided for the purpose accommodated eight to ten locomotives simultaneously. Over one hundred engines are usually coaled here daily, and during holiday seasons the number has been greatly exceeded; a considerable staff is therefore required. With the new installation the very largest engine can be coaled in less than three minutes, and not more than two men are required to operate it. The plant, as shown in the accompanying illustrations,¹ Figs. 991, 992, 993, and 994, and the photographic view, Fig. 995, consists of an underground or track hopper holding about 15 tons, over which runs a standard rail-track, an inclined bucket elevator and a tower containing the driving gear, a control platform and a coaling shoot projecting over the turntable siding. The coal wagons are brought one at a time over the underground hopper, and if they are of the bottom-door type their contents may be discharged into the hopper in the usual way. If they are of the end-door type, they are tipped by hydraulic rams. The coal is passed from the hopper down a shoot into the buckets of the conveyor. The buckets have each a capacity of one-third of a ton, and as they pass the hopper shoot at the rate of about eight a minute, the plant is capable of dealing with about 160 tons per hour, or say $2\frac{1}{2}$ tons per minute. As the capacity of the buckets is known, the quantity of coal delivered to any engine can be measured approximately by counting the number of buckets discharged. The construction of the buckets is illustrated in Figs. 996 and 997.

At the tower the buckets discharge their contents direct into a shoot, which leads the coal on to the tender. The driving gear consists of a 15 H.P. electric motor, transmitting through spur wheels. One of the two men employed attends to the moving and discharging of the coal wagons, while the other controls the starting and stopping of the conveyor and the coaling of the engines generally.

Compared with the coaling sheds previously employed the plant takes up very little room, so that it economises space, time, and wages. The charge for power used is very small indeed. The engineers state that the time now spent in coaling is less than the time taken to shunt an engine on to the turntable, turn it and move it away, and that an engine can be completely coaled without loss of time, while it is waiting its turn at the table. In other words, engines can now be coaled and turned in the same time that it took previously to turn them.

Installation for Coaling Railway Engines at Carlisle, London, and North-Western Railway, by Cowans, Sheldon & Co., Ltd.—This is very similar to the Camden Town installation just described, but in its construction advantage has been taken of the experience gained in the erection of that plant.

¹ These illustrations are reproduced from *The Engineer* of 2nd April 1915, by kind permission of the Editor.



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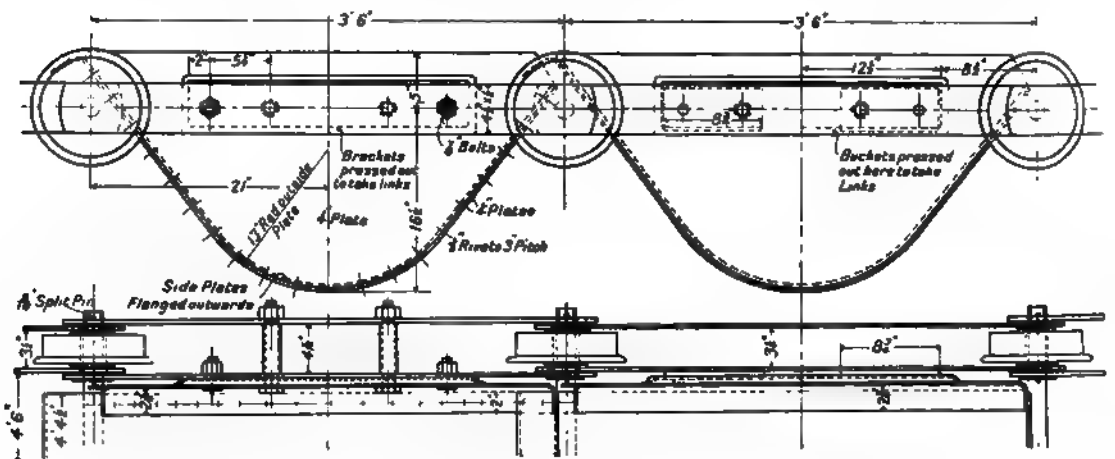
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Figs. 991, 992, 993, and 994. Locomotive Coaling Station of the London and North-Western Railway Co. at Camden Town.

Two hydraulic tips are here provided, instead of one, each having a 6-in. ram, a stroke of 6 ft. 10½ in., and a working pressure of 2,000 lbs. per square inch. The upper

Fig. 995. Photographic View of Locomotive Coaling Station at Camden Town.

end of the ram is provided with a crutch, which engages the rear axle of the coal-truck. One of these tips is at each side of the track hopper, so that whichever way the coal



Figs. 996 and 997. Details of Conveyor (Part Plan and Elevation) of the Locomotive Coaling Station, Camden Town.

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trucks arrive they can be discharged by either one or other of the tips, according to the position of the end door. Hopper-bottomed trucks are naturally equally suitable for bringing the coal. Coal is discharged into a track-hopper 18 ft. long. From the centre of the track upon which the coal arrives to that upon which the locomotives are

coaled is 22 ft., and the centre line of the elevator is exactly central between the two tracks. It was necessary to crank the lower portion of the track hopper in order that the coal should be delivered about 11 ft. sideways, so that the hopper is central both at the receiving and delivery point. The track hopper has a holding capacity of 20 tons, and is thus large enough to mix coal if necessary from more than one truck. Below the track hopper is the tension terminal of the conveyor, the centre of which is 16 ft. 6 in. below rail level. Both conveyor terminals are pentagon-shaped. Delivery of the coal is given at the upper terminal, a distance of 77 ft. 7 in. from the receiving terminal and 25 ft. above rail level. The pitch of the chain of buckets is 3 ft. 6 in., and there are in all fifty-six buckets, with a capacity of one-third of a ton each. The width of the buckets is about 4 ft. 6 in., while the speed of travel is 28 ft. per minute, so that eight buckets per minute will be discharged.

A cross spindle is placed between each pair of buckets, supporting them, and each spindle is provided with a substantial pair of trod wheels running upon double tracks for both the full and return strand of the chain of buckets.

A tower of structural steel, which is roofed in, supports the upper terminal, an upper and lower working cabin of 11 ft. by 14 ft. each, for the driver and his mate. A 20 H.P. electro-motor is also located in the upper cabin, together with the conveyor terminal, and drives the installation. The current is 400 volts, 50 cycle, 3-phase; the power is transmitted through two countershafts and trains of spur gear. The elevator buckets discharge through an oblique shoot direct into the tender, the outlet of the shoot being 13 ft. above rail level. The motor obtains its current from a high tension transformer in a compartment within the tower.

Locomotive Coaling Station, Dairycoates, Hull, of the North-Eastern Railway Co.—The North-Eastern Railway Co. was the first to follow the example set by the London and North-Western Railway Co. and erect a coaling plant at the locomotive sheds at Dairycoates. The installation, which is electrically driven, was supplied and erected by Spencer & Co., Ltd., of Melksham, Wiltshire, to the design of the Railway Company's chief mechanical engineer, Mr Vincent L. Raven.

The underlying principle of this coaling plant, which is illustrated in photographic view, Fig. 998, is similar to that of the one at Crewe. The sidings, together with the connecting road on which the coal arrives, are on a falling gradient of 1 in 95 to allow the loaded wagons to be lowered by gravity to the hopper for discharging and then run into an empty siding. The underground hopper has, in this case, a capacity of 20 tons, and the coal from this hopper falls on to a jiggling screen. The large coal passes through a crusher which reduces the lumps to such a size as will easily pass through the locomotive fire doors, and then deliver on to the elevator, while the small by-passes the breaker, and is conveyed direct to the elevator. The flow of coal from the hopper to the jiggling screen is regulated by a gate operated from the ground level. The crusher and jiggling screen are driven through suitable gearing by a 25 B.H.P. motor fitted on a platform in the hopper pit. The bunkers here also are divided, as at Crewe, into two compartments of 100 and 200 tons capacity, respectively, for the two different classes of coal used. Four delivery shoots are provided, two at each side of the bunkers for coaling the locomotives, thus allowing four to be coaled at the same time if desired. The delivery shoots are of the measuring type, holding 10 cwt. at each delivery.

Additions, not provided at Crewe, are two 15-cwt. electrically driven coaling cranes, for coaling the locomotives when the elevator is out of use. They are so arranged as to lift the coal in tubs from the ground level on to the locomotive, and can be slewed through an angle of about 150°. Under normal conditions the average number of

one end carried into a dash-pot, therefore, when the magnet is first energised, it requires several seconds for the plunger to operate and complete the electric circuit to the motor. This period of time may be regulated from five to fifteen seconds, allowing ample time either for the skip to receive its load or to discharge it at the respective termini. When the skip has nearly reached the uppermost position it encounters, successively, a slow-down switch, a stopping switch, and a starting switch. The rate of travel of the skip is about 140 ft. per minute. When it strikes the slow-down switch, resistance is thrown into circuit, cutting the speed to about one-half; the skip then proceeds to the stopping switch, engaging the stopping switch and the starting switch at the same moment. The stopping switch arrests the motor, while the starting switch only energises the magnet coil on the controller in the reverse operation. This allows the skip at the top several seconds in which to discharge its load before the circuit is completed and the

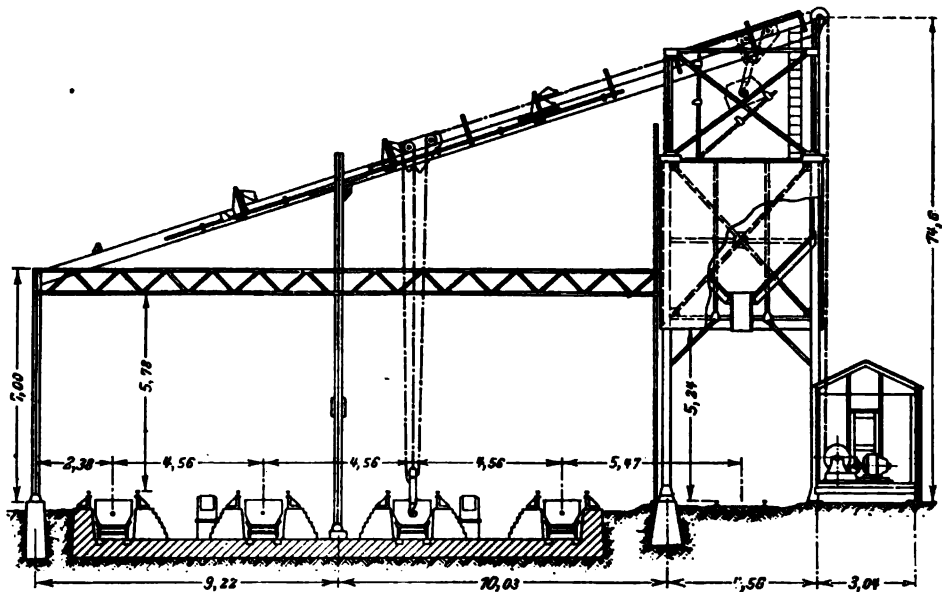


Fig. 1000. Typical American Plant for the Removal of Ashes from Locomotives.

(These dimensions are in metres.)

motor reversed. The machinery, therefore, continues to operate in the forward and reverse motion until the current is cut off at the electric main.

When gasoline or steam power only is available, the automatic reversing hoist is driven by belt from the gasoline or steam engine through a series of cams and clutches, so that the engine runs continuously in one direction, while the hoist reverses automatically at either terminus, leaving a period of time sufficient for the discharge or receipt of the coal. A number of these appliances have been installed and are satisfactorily at work in the United States.

Installations of a similar nature are built by the T. W. Snow Construction Co., of Chicago, Illinois.

Coaling Installation of the London and North-Western Railway Co. at Edge Hill, Liverpool.—This plant differs widely from all the foregoing, the principal feature is the solution of the difficulty of filling the bunkers without resorting

The early plants of this type required the constant attention of an attendant to reverse the machinery, whether operated by an electric motor, steam, or gasoline power. In the subsequent development of the art it was found expedient to operate such plant

Fig. 999. General View of Coaling Station of the Roberts & Schaefer Co., Chicago, Illinois.

automatically, leaving the attendant free to dump coal or to supervise the oiling of the machinery. This led to the introduction of an automatic reversing skip hoist controller for manipulating the motor. To start the machinery it is only necessary to push a button which energises a magnet on the controller. A plunger in the magnet or solenoid has

CHAPTER XL

COMPLETE HANDLING INSTALLATIONS FOR BOILER-HOUSES, GASWORKS, ETC.

THE coal-handling equipment of a boiler-house usually consists of an elevator in conjunction with one of several types of conveyors, or of a gravity bucket installation combining the work of an elevator and conveyor. In general, slow speed machinery is recommended for such work, as it is more immune from breakdowns, has a longer life, and costs less to maintain; on the other hand, it involves larger capital expenditure.

The driving mechanism should be substantial and yet as simple as possible. It should be borne in mind that the details of construction of any one type of conveyor, important as they may be, are not all-important, but rather should the general scheme of the equipment and the design in its broader features be adapted to the work required, so that the upkeep and working cost will be a minimum, and the system as a whole may do the work as efficiently as possible.

The mechanical appliances for handling coal and ashes have been fully described in the previous chapters, but the bunkers holding the coal for immediate use above the boilers justify more than a passing notice.¹

Rectangular hopper-bottomed bunkers are well known and frequently used, but the type of self-cleaning suspension bunker, either of boiler plates or reinforced concrete, requires a few general remarks. The construction is very simple. From two main supporting girders steel straps are suspended at frequent intervals, which are covered on the inside by steel plates, the steel straps taking the full weight of the bunker and contents and transmitting it to the longitudinal girders on each side. The maintenance of a steel plate bunker is comparatively high on account of corrosion, and hence the reinforced type has been introduced. With this latter system the steel straps forming the support are laid with ferroinclave (a special crimped steel sheet) or other reinforcements, with an inside lining of cement and an outside cement sheathing, the ferroinclave sheets forming the reinforcement for the concrete linings. Such bunkers are practically indestructible. Fig. 1001 gives an illustration of such a bunker in a large power plant, in conjunction with a travelling weighing hopper for the coal distribution from the bunkers.

The capacity of bunkers depends upon the interval during which the coal supply may possibly be interrupted, but generally provision is made for no longer a period than one week, and longer interruptions may be provided for by stock heaps in close proximity to the boiler-house, from which the bunkers may be replenished.

Coal bunkers of large capacity were formerly often placed in a separate building alongside the boiler-house, or the retort-house of gasworks, but the great advantage and saving in labour in having the bunkers located above the boilers or retorts, in order to feed them by gravity, is too obvious to require further comment. When once a week's supply is in suspension above the boilers or retorts no interruptions, owing to accidents to the

¹ See also the introductory remarks in Chapter XLI., "Storing of Coal and other Minerals in Stock Heaps and Silos."

conveying or elevating machinery, can occur, and there is generally time to repair breakdowns.

The Handling of Ashes and Clinkers.—This is a far more difficult problem, owing to the abrasive nature of these materials. They may also be very hot or dripping

Fig. 1001. Suspended Coal Bunker in Boiler-House.

wet. Their cutting nature causes excessive wear on machinery of any type which may be employed for handling them, and if hot they may cause distortion of parts of the machines with which they come in contact, in addition to which they may cause fire in the ash bunkers, or even explosions, if these receptacles are closed and thus prevent the escape of gases. Wet ashes damage mechanical conveyors and will not deliver readily,

whilst pneumatic installations will not handle them at all, while in cold climates the wet ashes will freeze together in the bunkers, making their discharge into trucks impossible, unless the bunkers are fitted with heating apparatus.

There is, however, no apparent reason why the ashes should be either too hot or too wet to be handled in suitable conveyors in well-managed establishments. If for some reason or other the ashes should be too hot or sopping wet, they can be handled intermittently by skip hoists, mono-rails, or by the car and skip system, which consists of a hopper on rails pushed either by hand or electricity, which collects the ashes from hoppers under the boilers, and an electric skip car to raise and discharge them into overhead bunkers. Of course the system will answer equally well for all ashes in all conditions. If the local conditions are favourable the ashes may be collected in a hopper under each boiler and at intervals discharged into railway trucks on rails which pass beneath.

Ash bunkers are generally square or cylindrical with a hopped base, and if closed they should be ventilated. Pneumatic plant, either actuated by vacuum pumps, steam or air jets, are nowadays installed in most large power-houses; they have incidentally the advantage that the flues, including those of the economisers, can be kept clean with a minimum of effort and expense.

The Use of Telfers in Gasworks and Power

Stations.—Telfers fitted with grabs are frequently used when handling coal, and with special tipping receptacles when handling coke. If the material to be handled is coal, it can be elevated from the cars, pits, stock heaps or barges, and without rehandling,

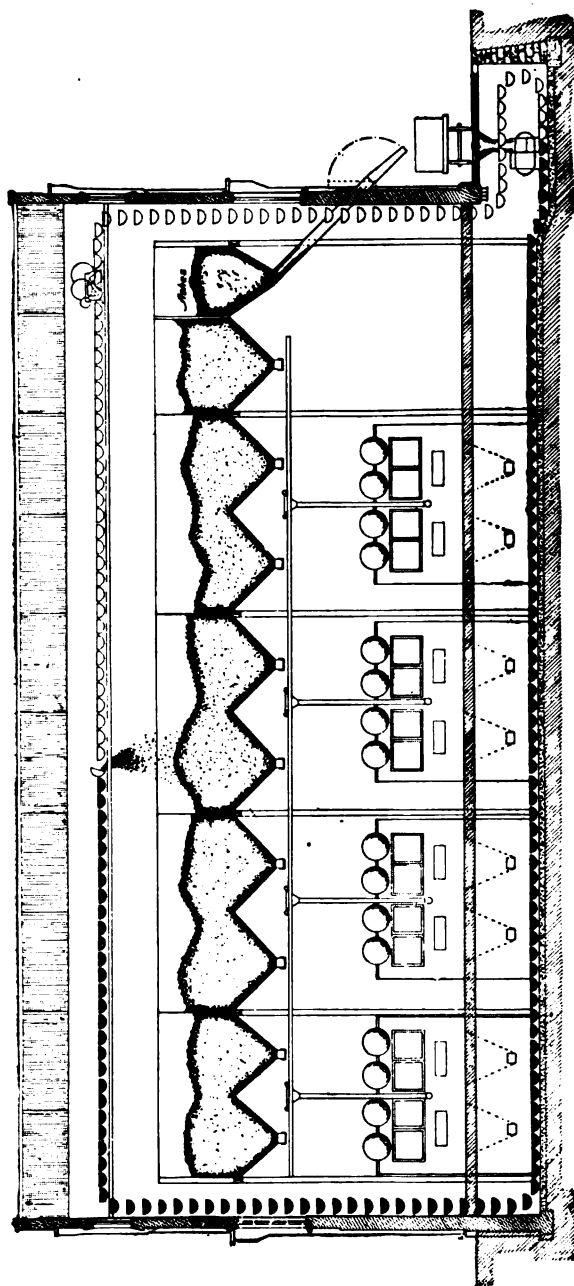
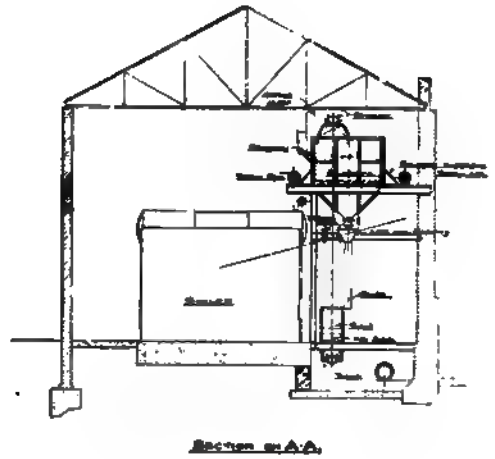


Fig. 1002. Gravity Bucket Conveyor at the Shepherd's Bush Station, Central London Railway.



cravan, near Aberdare, South Wales.

[To face page 691.]

can be transported to the storage yard, to overhead bunkers, or to the furnace door. The coal can be raised and carried from the storage yards by the same grab to the boiler-room. Electricity, through the telfer, hoist and bucket, does all the work, one telferherman the directing.

BOILER-HOUSE INSTALLATIONS

Coal-handling Plant of the Central London Railway Co. at Shepherd's Bush.—This is an early installation in which a gravity bucket conveyor handles both the coal and the ashes. The ashes are deposited in the end bunker, so that they can be shot into the same railway trucks which bring the coal, as will be seen from Fig. 1002.

A Typical Babcock & Wilcox Equipment of Coal and Ash Bunkers and Stock Yard is represented in Fig. 1003. It shows an arrangement of outside reserve coal storage with delivery into, and discharge from, the same, by means of a gravity bucket conveyor into overhead bunkers. This arrangement requires very little description, the drawing being self-explanatory. Briefly, however, it is as follows :—

Coal is delivered from the trucks into a receiving hopper, fed into the conveyor *via* a rotary filler, and either conveyed into the reserve coal storage outside, or carried inwards and delivered into the overhead bunkers.

Ashes can be taken from the basement under the boilers, and delivered into the ash bunker shown midway between the boiler-houses and the reserve coal store.

In discharging coal from the reserve store, a series of valves are operated by levers, and allow the coal to flow by gravity into a travelling rotary filler, which serves all the openings. This filler supplies and regulates the coal to the conveyor, which rises, and passing horizontally, delivers into the overhead bunkers.

Coal-handling Plant at the Avonbank Power Station, Bristol.—In Figs. 1004 and 1005 the general arrangement of this installation of the Bristol Corporation is shown. A combination of a Hunt automatic railway and a gravity bucket conveyor is used in this plant, the former being employed for carrying the coal from the receiving hopper and weighing machine on the river side to the shoot which feeds the gravity bucket conveyor.

The automatic railway wagon receives coal from a weighing machine on the tower, descends by gravity along the incline to a filler pit, into which it deposits its load and returns by means of the accumulated energy as already described.¹ From this point the coal is dealt with in the ordinary way, being fed through the automatic filler, after which it is carried upwards and inwards and dumped into the overhead bunkers, whence it is discharged by shoots into the stoker hoppers, the capacity being about 40 tons per hour.

As the coal used at this station is of a specially fiery nature, the plant has been provided with an arrangement for retrimming, as shown in the illustrations. To this end the coal bunker is fitted with four shoots (three of which are shown), through any one of which the coal when desired may be discharged into the conveyor by means of the movable filler, which is placed over the latter on the track beneath the boiler-house floor.

Coal and Ash Handling Plant of the Powell Duffryn Steam Coal Co., Aberaman, South Wales.—Figs. 1006, 1007, and 1008 show a system of overhead bunkers and the conveyor for serving them. The first half of the plant was supplied in 1906 by Messrs Babcock & Wilcox, and the extension half two years later.

The arrangement is quite evident from a study of the illustrations, and is in

¹ For further description of the "Hunt" Automatic Railway, see page 546.

accordance with the general practice, the coal being delivered by wagons into a receiving hopper, and the conveyor taking the coal from there by means of a filler, elevating, and carrying it horizontally above the overhead bunkers, and delivering into any section as required. From these bunker divisions the coal is delivered by means of special valves and shoots into the stoker hoppers.

Ashes are dealt with by the same conveyor, being delivered into an ash bunker outside the main building, and taken from thence by carts or other conveyances.

The normal capacity of this conveyor is 40 tons of coal per hour, but it can be increased to 50 tons if necessary.

Coal-handling Plant and Store at the Buenos Ayres Grand Central Electric Power Station, Argentine Republic.—Fig. 1009 represents a system of coaling boiler-houses direct from steamers or barges alongside the wharf.

Two gantry cranes, travelling parallel with the wharf, are capable of taking by means of grabs 1 ton charges of coal from the steamers or barges, delivering it into conveyors—carried on the horizontal girders of these gantry cranes—which in turn deliver the material into either one or other of a pair of conveyors marked *B* and *B*¹ on plan. These conveyors run in opposite directions, and both discharge on to another pair of conveyors marked *C* and *C*¹ running at right angles to them. The conveyors *B* and *B*¹ are of the patent tipping tray type (described on page 109), and have at certain times the further duty to perform of collecting coal from railway wagons underneath.

Two travelling cranes are carried on the gantries supporting these conveyors, which collect material from railway wagons on the ground line and deliver it into hoppers, to which they are yoked, these hoppers delivering the coal, and regulating the quantities, into conveyors *B* and *B*¹ which again deposit into conveyors *C* and *C*¹. These latter conveyors both deliver into and collect from the reserve coal silo, but before being delivered into the silo the coal is broken and weighed automatically in its transit from conveyors *B* and *B*¹ to *C* and *C*¹.

In discharging from the silos conveyors *C* and *C*¹ deliver into two other conveyors *D* and *D*¹, travelling in a similar manner to *B* and *B*¹, in opposite directions to each other, and delivering, therefore, right or left according to requirements. These conveyors deliver into overhead conveyors in the boiler-houses which supply the active bunkers.

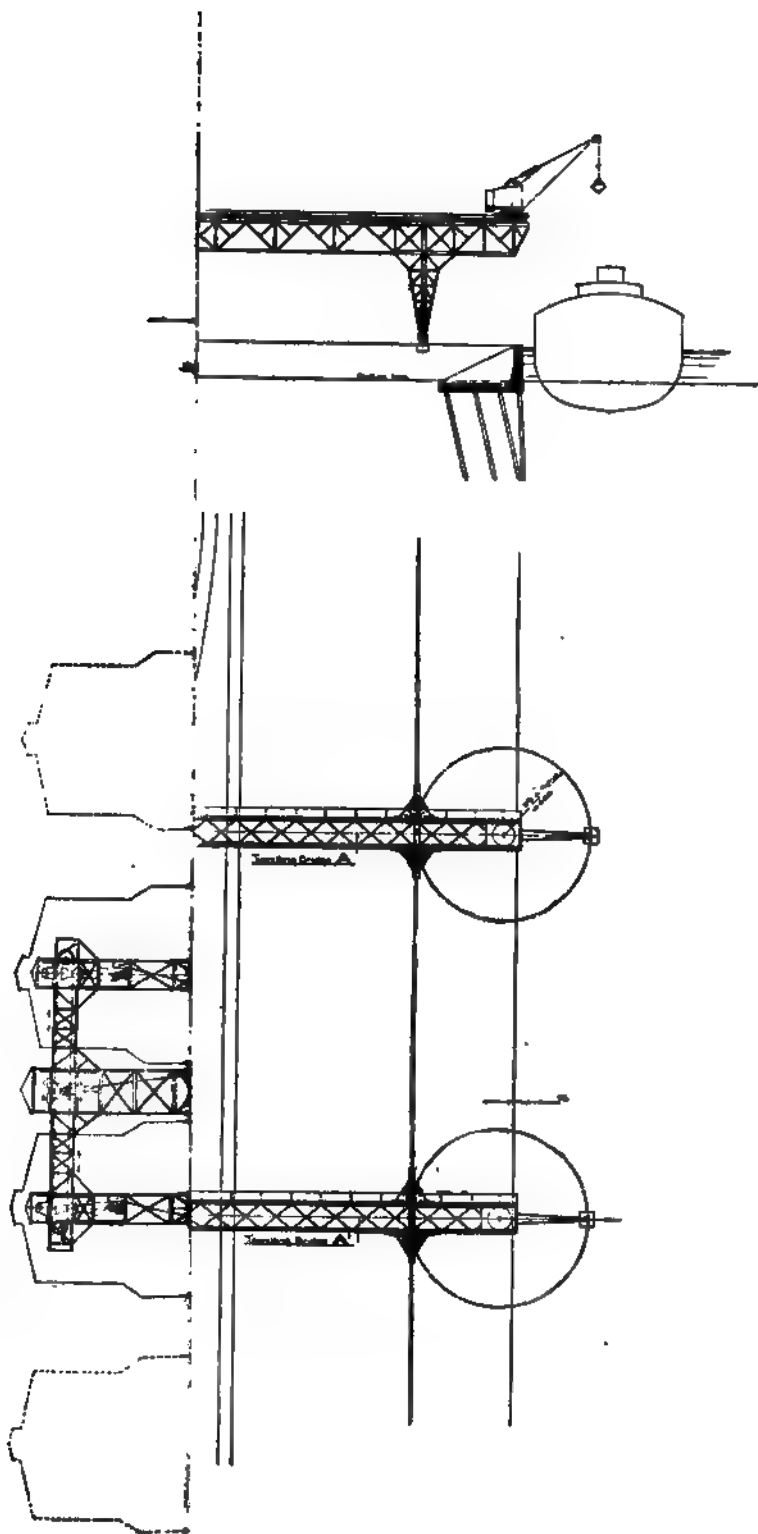
The coal can thus either be delivered direct from the ship into the overhead active bunkers in the boiler-houses, or into the reserve silos, afterwards to be delivered into the boiler-houses according to requirements.

The capacities of the various conveyors are given on the illustration, Fig. 1009.

This installation is by Babcock & Wilcox, Ltd.

Coal and Ash Handling Plant at the Massachusetts Cotton Mills, Lowell, U.S.A. (Darley System).—The general arrangement of this installation is shown in Figs. 1010, 1011, and 1012. This is claimed to be one of the largest pneumatic conveyor equipments ever constructed.

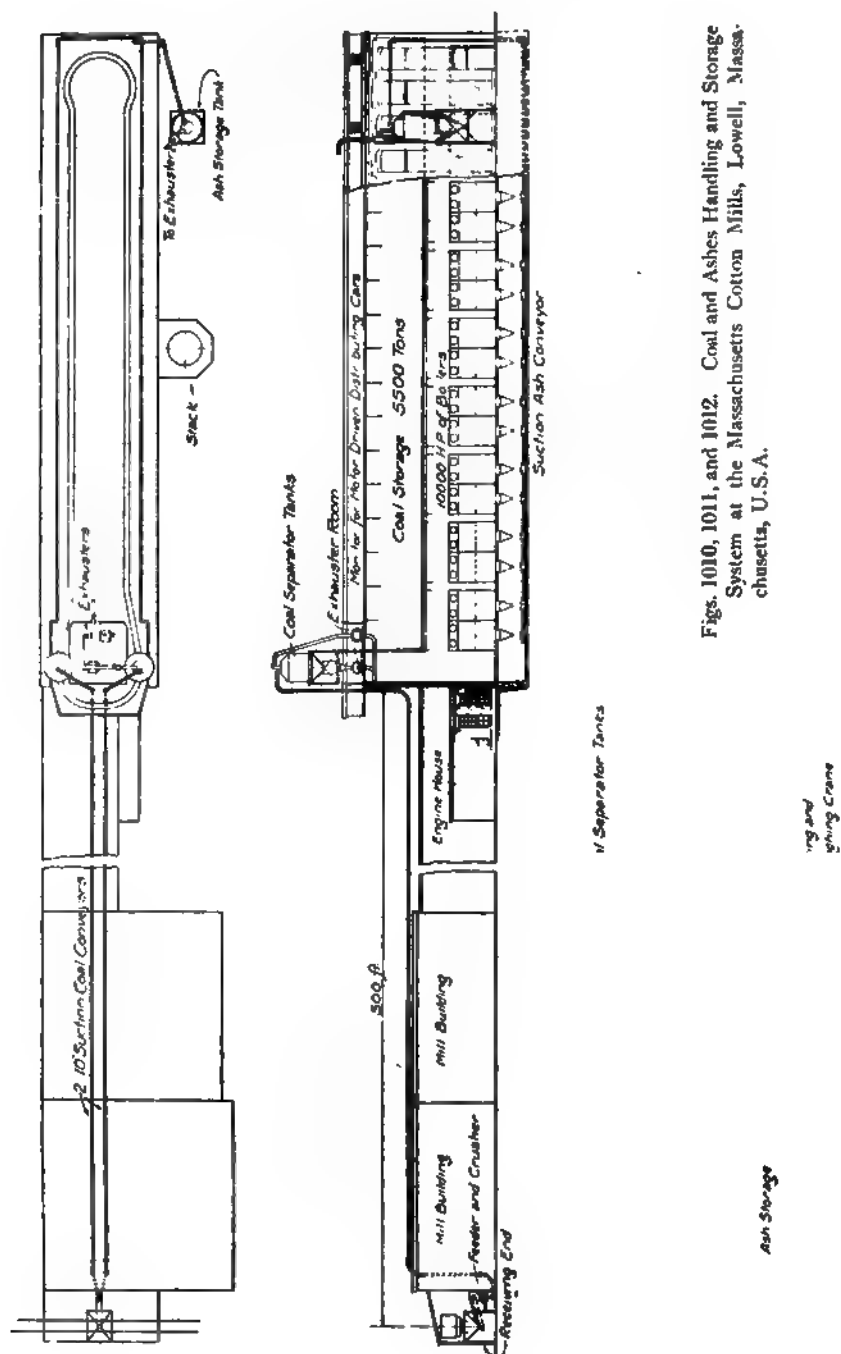
Coal is handled from the track hopper, some 600 ft. distant from the boiler-house, by means of two 10-in. suction conveyors. Beneath the track hopper is an automatic feeder and crusher for delivering the coal at a predetermined rate to the two intakes of the conveyors, which rise vertically to the roof of the building, and then extend horizontally across the intervening buildings to two 45-ton receivers mounted above the boiler-house, as shown. The two exhausters are located in the monitor of the building, and are so arranged that either exhauster can operate either suction conveyor. The coal can be dropped directly into one end of the storage bunker, or distributed by the motor-driven car. A 5-ton weigh-hopper, mounted on an electrically



prising:—

C ¹ .	Capacity: each 100 tons per hour.			
D ¹ .	"	"	50	"
E ¹ .	"	"	50	"

[To face page 692.



Figs. 1010, 1011, and 1012. Coal and Ashes Handling and Storage System at the Massachusetts Cotton Mills, Lowell, Massachusetts, U.S.A.

driven crane, is employed to draw the coal from the bunker and discharge it to the stokers. The structure is of steel; the bunker is of reinforced concrete, holds 5,500 tons of coal, and is framed in with the building columns.

The system of ash handling may be readily understood from the illustration.

This installation provides for handling the coal and ashes of 10,000 H.P. Babcock & Wilcox boilers, and is the design of the Guarantee Construction Co., of New York.

Coal and Ash Handling Plant of the Pierce-Arrow Motor Car Co., Buffalo, U.S.A. (Darley System).—The diagrams, Figs. 1013, 1014, and 1015, show a complete installation, using Darley pneumatic conveyors, for handling coal from railway wagons and from outside reserve storage, as well as dealing with the ashes from the boiler-house.

There are two batteries of boilers, and an 8-in. suction pipe extends from the ash pits to a 60-ton storage tank located over the adjacent siding, to deliver ashes as convenient directly to cars for removal from the yard.

A coal tank of 100 tons capacity is mounted at one end of the boiler-house, and is connected with a track hopper on the siding on which coal cars enter the premises. This suction duct connects, by means of a swivel elbow at the foot of the vertical riser, with a suction line extending out beneath the reserve coal storage. Ordinarily, coal is transferred from the 100-ton storage to the overhead bunker in the boiler-house by means of a motor-driven car, but the track for this car continues out of doors beyond the boiler-house on a trestle to provide for a reserve storage heap. A travelling hopper is employed, provided with scales, as shown in section, for feeding the boiler stokers. Both the coal and ash conveyors are operated by a single turbine-driven exhaustor, shown in one corner of the boiler-house.

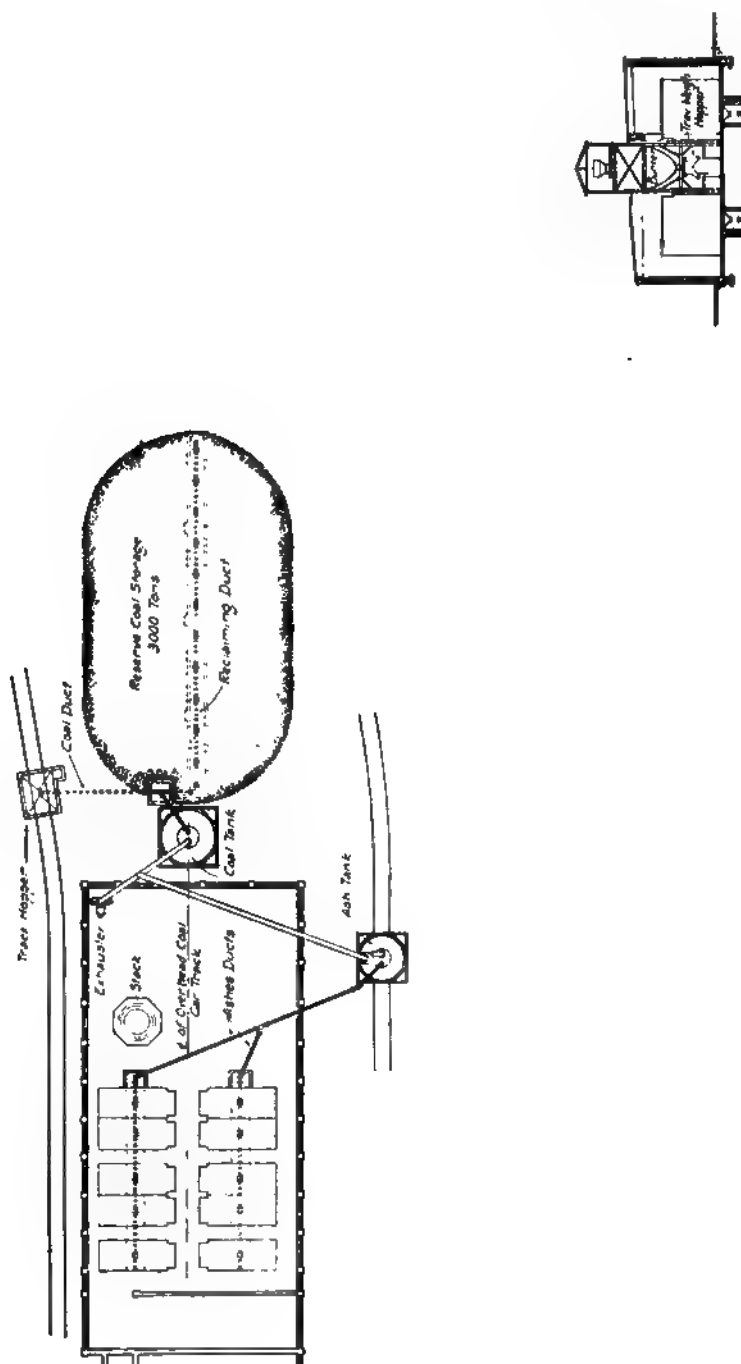
This installation is also the design of the Guarantee Construction Co., of New York.

Ash-handling Plant of the New South Wales Government Tramways, Sydney, Australia (Darley System).—Figs. 1016 and 1017 show an installation of pneumatic ash conveyors which has replaced a previous mono-rail with tipping bucket. The device is still in use, but it now handles coal only.

The suction ducts run along both sides of the basement and immediately beneath the ash pit. As the bases of the chimneys could not be tunnelled conveniently, the pneumatic pipes pass round them at angles of 45°.

Coal-handling Plant of Borough of Walsall Electricity Works.—An external view of this is given in the frontispiece. The coal storage yard is about 160 ft. long and 60 ft. wide, and beneath it a tunnel has been constructed from end to end in reinforced concrete. The coal-handling plant consists of a jib crane, an Avery coal-weigher, and a gravity bucket conveyor. By means of a grab on the jib crane the coal is raised from the barges lying alongside to the weigher, where the amount of each load is automatically recorded. From the weigher the coal passes automatically *via* a receiving hopper and stationary filler into the buckets of the conveyor. From this the conveyor is carried above the coal storage yard on a steel supporting structure and to the boiler-house bunkers, and returns beneath the coal storage yard by way of the tunnel already referred to. In this tunnel there is a portable filler into which the coal is fed from the coal store through shoots fitted with regulating valves, so that the coal can be delivered to the conveyor buckets from any part of the store, and different qualities of coal can be mixed by filling the buckets at different points alternately.

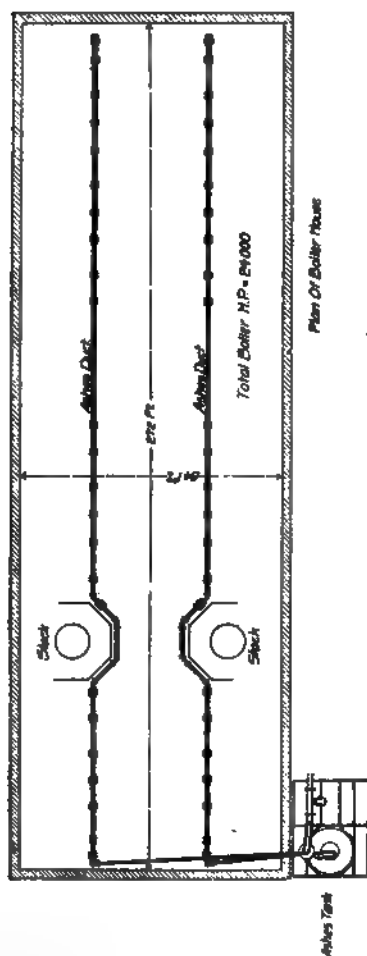
The conveyor is so arranged that coal can be conveyed from the receiving hopper to any part of the coal storage yard, and from any part of the coal storage yard to the



Figs. 1013, 1014, and 1015. Coal and Ashes Handling and Storage System of the Pierce-Arrow Motor Car Co., Buffalo, New York.

boiler-house bunkers, or it can be carried direct from the receiving hopper to the bunkers if required.

From the boiler-house bunkers the coal passes through measuring drums and shoots



Figs. 1016 and 1017. Ashes-handling Plant on the Darley System of the New South Wales Government Tramways, Ultimo Power House, Sydney, Australia.

to the hopper or the automatic stokers, the shoots being bifurcated at the bottom ends, in order to distribute the coal evenly in the stoker hoppers.

The jib coaling crane is designed for a maximum radius of 40 ft., and is proportioned for handling a grab with 25 cwt. of coal. Three motions are provided, *i.e.*, hoisting, luffing, and slewing, which are effected by a single electric motor of 30 B.H.P. The speeds are—hoisting, 85 ft. per minute; luffing, 150 ft. per minute; and slewing, $1\frac{1}{2}$ revs.

per minute. The motor is started without load and runs continuously in one direction, thereby avoiding the heavy rush of current consequent upon starting a load or reversing it again by means of a controller. The motor is geared through Hollick friction gear to the main driving shaft, which also runs continuously in one direction, and this shaft is fitted with reversing bevel gears for slewing and luffing, and with a steel pinion for hoisting.

The absence of any necessity to make or break electrical contact ensures quick, smooth, and economical operation. The load is lifted by the application of a brake to the gear, and hoisting can be started quite gently and smoothly by the gradual application

Weigher

Fig. 1018. View of Central Portion of Coal-handling Plant of the Newport Power Station, Melbourne.

of this brake. The luffing gear is so designed and balanced that the load travels in a horizontal direction and at practically a uniform speed, which drops as the jib approaches the maximum or minimum radius, the construction being such that these limits cannot be exceeded. As no work is done on the load when luffing, and the jib is balanced in all positions, the only force to be overcome is the friction of the working parts, the power required being therefore small.

Being balanced in every position the jib has no tendency to run in or out, except under power, and it is not dependent upon the brake, which is only provided to give greater control and to prevent the jib being moved by a high wind.

The capacity of the gravity bucket conveyor is 30 tons of coal per hour, with a chain speed not exceeding 48 ft. per minute, and is actuated by an electric motor of 10 B.H.P.

The operating gear is in the boiler-house, and is entirely under the control of the boiler-house staff.

The central portion of a very similar handling plant, by the same engineers, is shown in Fig. 1018. It was erected to the order of the Victoria Government through their consulting engineers, Marz & MacLellan, for the Newport Power Station, Melbourne. This view will be of assistance in elucidating the foregoing description. The principal difference between this and the Melbourne plant is that the latter has three gravity bucket conveyors, whereas in the former, one only serves for all purposes.

GASWORKS INSTALLATIONS

Coal-handling Plant at the Darmstadt Gasworks.—A Bradley conveyor is used here running through the whole of the building, as shown in Fig. 1019. The top run is high enough to feed three band conveyors. These deliver to the coal silos in the store, which are hopper-bottomed, and are each provided with fifteen Weiss feeders (which are illustrated in Figs. 162 and 163). These deliver the coal into three reciprocating conveyors placed in tunnels beneath the silos, the delivery ends being visible in the illustration, and also the shoots which lead the coal on to the lower run of the Bradley conveyor. The coal thus taken from the store is conveyed by means of the Bradley conveyor to the top of the building, where it is fed into push-plate conveyors. These in their turn fill the coal hoppers over the retorts.

Coal and Coke Handling Plant of the Bristol Gas Co.—This is a very complete installation, and illustrates the mechanical handling of coke and coal in all its stages. It is the design of Mr D. Irving, M.Inst.C.E., engineer of the Bristol Gas Co.

Figs. 1020 and 1021 give a general plan and elevation of the installation.¹

The coal is taken from the holds of vessels in the tidal river Avon, then weighed and broken to a suitable size to be further treated by the elevator and conveyor which remove it to the inclined retorts. These receive the coal without any such manual labour as would be necessary in the case of horizontal retorts. The coke, after carbonising, leaves the inclined retorts by gravity, and is conveyed by a hot coke conveyor into a yard at the opposite end to that in which the coal is received. The unloading of the coal is effected by means of a steam crane and a Hone grab. This part of the installation is capable of dealing with 30 tons of coal per hour. The grab delivers its load into a hopper and weighing machine which discharge either direct into the elevator well, or, if the coal is not sufficiently small, it passes through a coal-breaker before going to the elevator. The elevator discharges at the top into a push-plate conveyor which distributes its load into overhead bunkers. The elevator and conveyor as well as the coal-breaker are driven by a gas engine of 12 H.P.

The original plant was of sufficient capacity to feed an additional retort-house now erected alongside. The coal bunkers are fitted with measuring devices and shoots, to convey the coal from any one to the retorts, which can thus be charged without any manual labour. As already stated, the hot coke is removed by a conveyor suspended from girders beneath the retort-house floor. Above it, along its entire length, are water pipes for quenching the coke as it passes on its way. Several of the conveyor covers can be removed at the point where coke has to be received, the remainder of the plates continuing undisturbed, so that the men in charge are not inconvenienced by the vapour always arising when hot coke is quenched. The plates move backward away from the

¹ The Author is indebted to Mr D. Irving for the description and illustration of the plant.

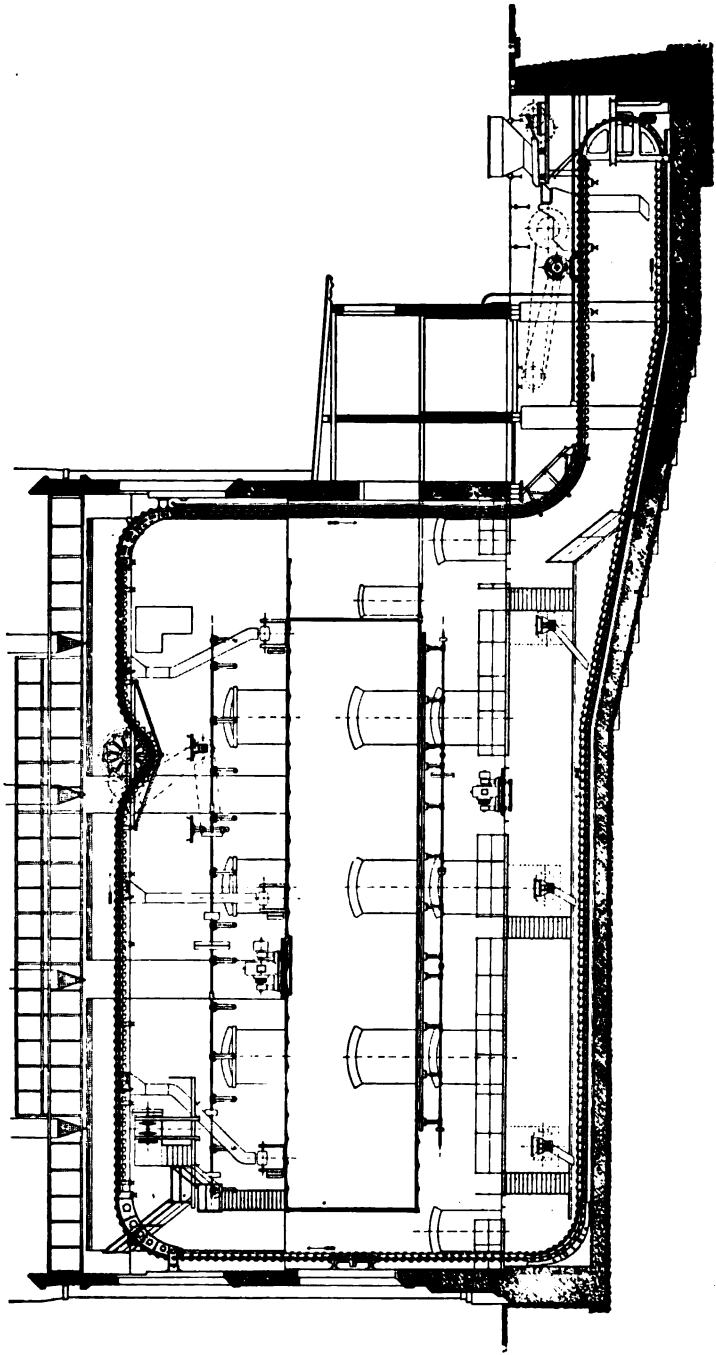


Fig. 1019. Coal-handling Plant at the Darmstadt Gasworks.

Figs. 1020 and 1021. Plan and Elevation of Coal and Coke Handling Plant of the Bristol Gas Co.

retorts, to form a shoot for the reception of the coke, and at the same time shield the men in charge from the heat. The conveyor trough is 2 ft. 3 in. wide, and is constructed of two channel irons with a wrought-iron plate riveted to the bottom, which is also fitted with a renewable iron strip. The return run of the chain is carried overhead on guide pulleys. On leaving the retort-house the conveyor ascends an incline of 30° and delivers the coke, first to the screen which removes the breeze, and thence by another conveyor, partly inclined and partly level, which deposits the coke in a heap on the yard. The erection of overhead receptacles for the coke is contemplated, so that its discharge into wagons can also be effected without manual

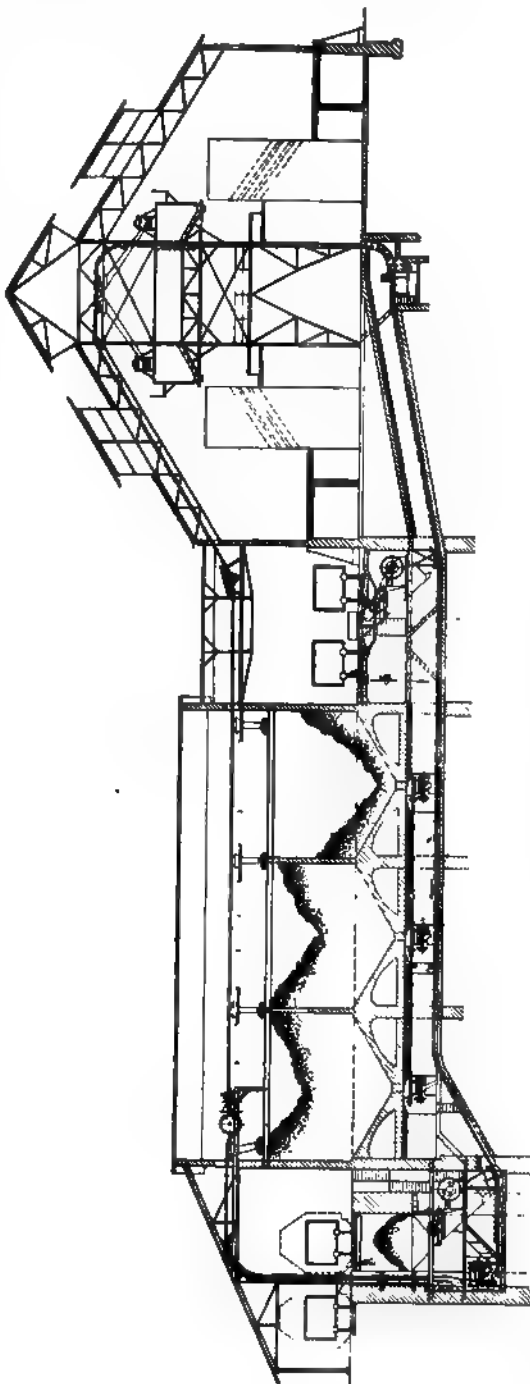


Fig. 1022. Coal Wagon Discharging its Load.

labour. The end of the coke conveyor extends so near to the river bank that the coke can be loaded by a shoot into coke barges. The highest end of the conveyor is 23 ft. above the ground, thus forming a large stock heap. The coke conveyors and the screen are driven by an 8 H.P. gas engine, erected in a small engine-house at the end of the building opposite to that in which is installed the gas engine driving the coal-handling plant.

Coal-handling Plant at the Nuremberg Gasworks.—

This plant is on similar lines to that at the Darmstadt Gasworks, but in this instance two Bradley

Fig. 1023. Section through Coal-handling Plant at Nuremberg Gasworks.

conveyors are used, with a capacity of from 45 to 50 tons per hour. The coal wagons here discharge their load into hoppers (see Fig. 1022).

The large coal is then conveyed to the coal-breaker, after the "slack" has been sifted out. Having left the breaker, it is deposited in one of the conveyors. The advantage of having two conveyors is obvious, as in the first place two railway trucks can be discharged at almost the same time, and further, one of the conveyors can be used for taking coal from the store to the retort-house, while the other is receiving coal. Having the conveyor in duplicate is also a safeguard against breakdowns.

A section through the installation is shown in Fig. 1023, while Fig. 1024 shows a section through the coal stores. In both views the band conveyors at the top and

Fig. 1024. Section through the Coal Stores at Nuremberg Gasworks.

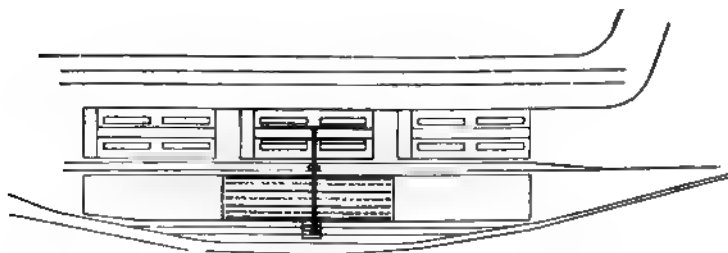


Fig. 1025. General Plan of Complete Installation.

the reciprocating conveyor beneath the silo bottoms can be seen. Fig. 1025 gives a key plan of the complete installation.

Coal-handling Plant at the Brentwood Gasworks.—The Brentwood Gasworks have a small but completely automatic coal-handling installation. Figs. 1026, 1027, and 1028 give two elevations and a plan. The coal arrives in ordinary trucks with hinged end doors; is then discharged by means of a hydraulic tip, and is deposited in a wrought-iron hopper, capable of holding the contents of the truck, about 10 tons. The coal, after being broken in the coal-breaker, is elevated to the top of the coal store, where it is conveyed by a Zimmer patent conveyor to the extreme end, or to any intermediate point of the store. Beneath the conveyor are fitted six tipping shoots, by means of which the coal can either be dropped to the bottom of the store or into coal pockets, which are best seen in the cross section, Fig. 1027. These pockets are quite an innovation, and are the design of Mr R. M. Couper, the then engineer of the gasworks. They terminate in such a position that the scoop for feeding the retorts can be filled from them

without the use of a shovel. Whenever the pockets are empty, and no coal is being taken in, the supply can be drawn from the coal store by means of a second Zimmer conveyor located in a tunnel under the floor of the store, when it can be elevated and conveyed by the plant already described.

The whole installation is driven by a steam engine of 10 H.P., which manipulates the coal breaker, the two conveyors, the elevator, and also the pump which works the hydraulic tip.

This installation was designed by the author.

A considerable number of the most important gasworks in this country are now fitted with telfer installations, which not only bring the coal to the stores and bunkers, but which serve the dual purpose of removing the incandescent coke from the retorts to the yard. Such an appliance is illustrated and described on page 375. Owing to the difficulty of illustrating such plant, no attempt has been made to do so in this chapter. The reader is referred to Chapter XXVII., Mono-Rails and Telfers; and Chapter XLI., Storing of Coal and other Minerals in Stock Heaps and Silos, in both of which this matter is dealt with.

CHAPTER XLI

STORING OF COAL AND OTHER MINERALS IN STOCK HEAPS AND SILOS

COAL and other minerals which do not materially deteriorate through the influence of the weather when stored in the open are generally accumulated in stock heaps or piles, over which mechanical equipments are erected for their deposition and withdrawal. Other materials, such as salt and chemicals, are similarly stored but under cover, as also is coal for household purposes.

The mechanical equipment varies with the nature of the material. Coal and coke requiring gentle treatment to prevent breakage should preferably be deposited by continuously working conveyors and elevators, and less frequently by intermittently working devices, such as grabs suspended from telfers and other mono-rails, or by the Hunt Automatic and other self-unloading railway trucks. This naturally also depends on the coal itself, whether it is in large or small pieces, and on the degree of friability; American coal being less friable, for instance, than the average English coal. Materials such as ore, which are not affected in value by breakage, are generally handled by intermittently working devices.

The withdrawal or reclaiming of the stock from the pile is likewise effected in various ways, which are principally influenced by the friability or otherwise of the materials. Those immune from deterioration by breakage are generally withdrawn by grabs or shovel-buckets, whilst the best method of withdrawing coal and coke is by continuously working conveyors located in culverts beneath the pile, and in such cases the mineral store is not infrequently heaped over a ferro-concrete hopped structure, from the lowest portion of which it is withdrawn through openings fitted with gates which communicate with the culvert and its conveyor. There are, of course, exceptions to this, and friable materials are sometimes both deposited and withdrawn by grabs or shovel-buckets (suitable grabs of large capacity do not injure average coal more than some continuously working conveyors), as such installations are less costly in the first instance, the same appliance being used for both stocking and reclaiming.

Local conditions also play an important part in the choice of the most suitable means to be employed. For instance, where coal is to be unloaded by grab from barges and delivered on to a stock heap, it may be better to retain the coal in the grab, telpher it to the pile and there gently lower it, than to transfer it to a conveyor, as this would cause more damage. On the other hand, if the coal arrives by rail and is unloaded by a tip, an elevator and conveyor, or combination of the two, would be chosen. When topographical conditions are favourable, so that the store can be approached from a higher level, or if there is sufficient space for trestle-work or embankments, the material can be brought by rail and hopper wagons, and discharged into stores or silos by gravity. Or if the store can be arranged on the hillside, both loading and unloading can be most conveniently and economically arranged.

Whatever general arrangement may be chosen for storing coal, the most important consideration is to deposit it gently with the minimum of drop, and when once laid down,

break bulk as rarely as possible. Some breakage of the coal is unavoidable, however gently it may be handled; mechanical handling, being inflexible, necessarily involves a number of transfers from hopper to shoot and from shoot to mechanical appliance, and so forth, but the fall at each point of transfer can and should be reduced to a minimum.

Coal is handled with care at the colliery, and after journeys of often hundreds of miles is delivered in good condition containing, perhaps, only a small percentage of slack; it is paid for at a rate proportionately high to its size and, if carelessly handled at the storage installation, it arrives at the furnace door at a greatly reduced value. American coal, as has already been mentioned, is harder than our average coal, and that used for railway engines in that country is also smaller, but notwithstanding this the breakage at some of the American coal stores is appalling. At the Session of the International Railway Fuel Association, held at Chicago in May 1913, this subject was discussed at great length, particularly in view of the modern locomotive coaling stores. Some details concerning a case of the Chicago Rock Island and Pacific Railroad revealed the fact that some coal which was delivered from the colliery with 42 to 45 per cent. of slack contained, after being handled by the coal plant, 72 to 75 per cent., and in the case of lump coal which contained only 25 per cent. of slack this was increased to 65 per cent. This incidentally shows how much lump coal suffers from rough treatment.

Coal handled by grab must of necessity suffer some damage, and particularly so if it has to be grabbed twice, *i.e.*, on delivery and on withdrawal, as may be the case with a stock pile without subterranean facilities; if large grabs are chosen, however, and those with gentle action, it may be possible to effect no more breakage than if the coal were transferred with a shovel by hand.

Spontaneous Ignition.—An important precaution when storing coal is to guard against spontaneous ignition, and to this end it is usual not to heap bituminous coal higher than from 15 ft. to 20 ft., but this must, however, depend upon the nature of the coal. The Western Fuel Co. on the great American lakes store bituminous coal 30 ft. high. Warm rain during or shortly after stacking coal, as well as the compression, and the effect of dumping from some height, are elements of danger. The height of storage does not apply so much to silos as to stock heaps, as in the former the coal is withdrawn from the bottom and the whole mass is therefore set in motion whenever some is withdrawn. This also applies to piles with culverts beneath.

Some useful points on this subject were given by Mr Irving, the President of the Southern Association of Gas Managers.¹

At the Stapleton works of the Bristol Gas Co., of which Mr Irving has charge, all coal is stored in the open. The stores are 450 ft. long and 72 ft. wide, paved with blue brindle bricks and thoroughly drained. Coal is delivered into the stores by two sets of overhead rails, carried on steel girders, which are supported by iron columns. The coal is dropped from hopper-bottomed railway trucks to the ground, and is stored to a depth of about 20 ft. During the past few years the Bristol Gasworks have been troubled with cases of spontaneous combustion. Great care has always been taken with the coal stocks, especially with those coals that were known to have any tendency to heating. A number of 1-in. pipes, to each of which a letter or number is attached, were usually inserted throughout the stock of coal, into which a thermometer could be lowered, and the temperature observed and daily recorded; and when any part of the stock gave indications of heating, that portion was worked out as soon as possible. It has rarely been found, even with the most active coals, that the rise of temperature would exceed

¹ From *The Iron and Coal Trades' Review*.

from 3° to 5° C. in twenty-four hours—that is, in the first stage of heating. But after a certain degree is attained, the action is much more rapid; and where air is available it is destructive.

Various theories have been put forward to account for the spontaneous combustion of coal; and they may be summed up under two heads, viz., (1) the decomposition of iron pyrites, and (2) the oxidisation of the coal. In the case of coal mines, there is a third theory—that of friction. However this friction may operate in coal mines, with regard to the cases under consideration friction as a cause of heating may be dismissed.

It is generally admitted that in the presence of moisture pyrites undergo oxidisation and disintegration, furnishing additional fresh-cut surfaces of coal to absorb oxygen; a theory which is not supported by the latest investigations as being the cause of spontaneous ignition.

Coal varies considerably in chemical composition and also in physical structure. Given a number of fine coal particles containing rich hydrocarbons in the presence of moisture and atmospheric oxygen, and we have all the elements required.

Heating always takes place in the small coal; but cases have been known where large coal, and also nuts, lying against small, or covered by small, have developed spontaneous combustion. It would seem in some cases that the interstices, or air spaces, formed between the large and nut coal provided the necessary atmospheric oxygen which, acting upon the hydrocarbon particles of the small coal, sets up chemical action and the heat produced develops a certain peculiar chemical change in the coal. One of the first indications of heating is the steam, or vapour, which usually escapes from the stack by the line of least resistance, which may be far removed from the seat of the cause. As the heat develops, certain gases are evolved of the acetylene series, which give off a distinctive and peculiar odour, exactly the same as that found in coal mines. The odour is characteristic, and exclusive to the gases evolved from spontaneous combustion. No one could mistake this odour, which can be detected even at a considerable distance.

Mr Irving states that he suspects that there is some kind of chemical action induced when coals from different collieries are mixed together, different to some extent from simple oxidation. Oxidisation is certainly one cause, if not the chief cause, of spontaneous combustion.

Coals stacked not more than 6 or 7 ft. deep never showed any tendency to heating. In this case the heat of oxidisation is carried off in the atmosphere, without raising the coal to the temperature necessary to induce active or destructive chemical change, and little or no damage is done to the coal. Attempts have also been made to ventilate by running air shafts through the coal stack; but the latter state of that coal has been worse than the first, because the air, instead of keeping the coal cool, supplied the necessary oxygen, and greatly facilitated the destruction of the coal. This no doubt depends upon the size of the air shafts. Coal should, of course, in all cases be received as dry as possible, and care taken so that no damp coal is covered up with dry.

Mr G. H. Hutchinson, chief engineer to the North-Western Fuel Co., St Paul, Minneapolis, United States of America, says:¹ “The first step in handling a coal fire is to get direct access to the fire by rehandling the hundreds, and frequently thousands, of tons of coal within the inverted cone tributary to the small area at the bottom of the pile, where the fire starts. It is sometimes also necessary to isolate the burning area to prevent the fire spreading. After the

¹ In a paper on “The Handling of Coal at the Head of the Great Lakes,” presented at the Spring Meeting, St Paul, Minneapolis, 1914, of the American Society of Mechanical Engineers.

fire is uncovered, it can be extinguished by the use of water and the rehandling of the smouldering or burning coal. The application of water, however, to the top of the original coal pile is ordinarily useless and frequently increases the fire. While the liability to spontaneous combustion cannot be entirely eliminated, a clean dock surface and the absence of combustible foreign matter within the coal pile, and, after the coal is in storage, careful watching and prompt rehandling upon the first indication of heating, reduce the liability to a minimum."

As all mechanical appliances for mineral stores have been fully dealt with in previous chapters, it will suffice to give a number of typical examples showing the general arrangement without entering into the details of their construction.

Stock Piles on the "Dodge" System.—Such installations are essentially American. In this country they are not so necessary, owing to the closer proximity of the coal fields to the principal centres of consumption—such as blast-furnaces—and the facilities for rapid and regular delivery, except perhaps as a safeguard against the effects of labour troubles, trade booms, etc.

Stock piles on this system are almost exclusively used for storing anthracite coal, as bituminous coal cannot be stored in such high piles, which are frequently 60 ft. high and 200 ft. in diameter. There seems, however, no reason why such appliances should not answer equally well for storing other minerals. For storing anthracite coal the "Dodge" system is eminently useful, as the demand for that coal fluctuates greatly, and if stored in large quantities between the coal fields and the market, a continuous instead of a spasmodic working of the mines becomes possible and a convenient base of supply is provided.

Mr George E. Titcomb, of New York, read an interesting paper on "Hoisting and Conveying Machinery" before the American Society of Mechanical Engineers in 1908, from which the following description has been taken. The standard "Dodge" plant consists essentially of a push-plate or chain and flight conveyor supported by shear trusses DD (Fig. 1030), constituting a trimming machine which piles the coal with a minimum of breakage, delivering it upon the ground or at the ascending apex of a conical pile as it is formed.

The withdrawal or reclaiming of the coal is begun by the open side conveyor AB, which is pivoted at A and runs on a number of circular ground-level tracks extending between and over the area to be covered by the piles. This conveyor works against the edge of the pile, and follows up the receding edge as the coal is removed; it is operated by power, and is so devised as to be fully under the control of one man. All the coal is tributary to the reloading conveyors, and is carried without intermediate transfer up the incline to the reloading tower C, where it can be delivered either directly into cars or after having first been screened.

In short the "Dodge" system, as usually applied to open-air storage on levelled ground, consists of two trimming machines and the pivoted ground conveyor which travels radially between them (see Figs. 1029 and 1030), forming one group or unit. A coal storage plant consists of a number of these groups, which may be of equal or of varied capacities. The shear trusses are fixed to correspond with the angle of repose of the coal, the front truss of each group, *i.e.*, the truss adjacent to the track-hopper or receiving point, containing the conveyor. This conveyor runs in a trough, having for a bottom a continuous steel ribbon about 12 in. wide, which is wound upon a drum at the foot of the truss, and is paid out only as demanded by the formation of the pile; this feature provides a gentle discharge of the coal and prevents breakage.

Modifications of the standard "Dodge" system have been made to meet local

Fig. 1028 and 1029. American Scraper Conveyor for Building Stock Piles ("Dodge" System)

conditions. Hillside storage has been increased by mounting the trimmer conveyors on cantilever trusses to fully command the storage area after the initial and comparatively small gravity capacity has been reached. Where a continuous or oblong pile of maximum capacity is needed, instead of a conical one, a travelling trimmer is used, supported at the lower end on a power-driven truck, and at the upper end on a track supported by columns. Stocking or reclaiming is accomplished as in the standard group plant; the reloading machine being of the traversing instead of the pivotal type.

Where climatic severity makes covering of the coal necessary, the "Dodge" system has been found especially adaptable. A prominent installation of this kind employs a circular building with trussed dome-shaped roof. The coal is brought to the dock by boat, and unloaded by a tower hoist, from which it is spouted by gravity to the shoot of the trimmer conveyor. The construction of the trimmer permits it to be mounted on one of the roof trusses of the building. The reclaiming from the pile is effected by means of the pivotal reloader, which commands the inner circumference of the building, and delivers through floor openings to a push-plate conveyor running horizontally in a tunnel, from a position beneath the centre of the pile to a point outside the building. From here it rises on an incline to the reloading tower from which it delivers over screening shoots to cars. No exterior bracing is required for these buildings, as they are strengthened against bursting pressure from the mass of coal by a continuous circular bulkhead, which is supported free of the floor by anchor bolts extending inwardly from the I-beam posts of the annular wall.

In another type of covered storage plant the house area is of rectangular form, the building being divided to store equal quantities of egg, stove, and nut coal, the aggregate capacity totalling up to 100,000 tons. The equipment consists of three standard "Dodge" trimming conveyors for stocking the coal; three open-top carriers running in underground tunnels for reloading; three reloading towers provided with screens; three gravity-discharge transfer conveyors; and three screenings conveyors. The three trimmer conveyors and three transfer conveyors, or three reloading conveyors and three transfer conveyors can be operated simultaneously. Each machine handles 1,500 tons per day of ten hours.

The power plant for a "Dodge" system installation may include steam or electrical equipment, the generating outfit comprising a central unit from which distribution may be effected through a piping or wiring system to convenient points for direct operation. The equipment of a large plant of eight piles of 60,000 tons each includes four 16-in. by 20-in. 150 H.P. engines, so located that one engine drives the machinery of each two-pile group. In a 240,000-ton plant two 225 H.P. alternating current, 440-volt, 25-cycle, 3-phase motors drive the machinery of the 60,000-ton piles, while that of the 30,000-ton piles is controlled by motors of 150 H.P.

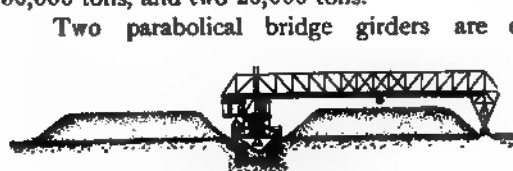
In 1906 a 200,000-ton covered anthracite storage plant on this system for stocking coal 60 ft. high was installed on Section 2 of the North-Western Fuel Co.'s Superior Dock No. 1, and in 1910 an addition was made which increased the storage capacity of this plant to 265,000 tons.

The capacity of the plants erected under the "Dodge" system aggregates a total of about 5,000,000 tons. While official figures are not obtainable for publication, it is guaranteed that the labour cost of either stocking or reclaiming on an active plant will not exceed four cents (say 2d.) per ton, pre-war.

Coal Store of the Philadelphia and Reading Railways at Richmond Harbour, Philadelphia, United States of America.—This is probably one of

the largest coal stores in the world, the harbour of Philadelphia being the centre of the very extensive coal traffic of the Reading Company, who own not only the collieries, but also harbours, railways, and ships. The coal arrives from the collieries in complete coal trains, the contents of which are, if possible, discharged direct into the ship, being drawn up inclines on to staiths where the trucks discharge through bottom doors and by gravity shoots into the vessels.

It is, as a rule, impossible to entirely dispose of the coal thus, so it is piled up in a stock heap which will hold 180,000 tons. The store consists of six cone-shaped piles (on the "Dodge" system), two of which will hold 40,000 tons, two 30,000 tons, and two 20,000 tons.



Two parabolical bridge girders are erected to form an angle with each other, slightly larger than the angle of repose of the coal; these girders are held in position by guy ropes. The coal is discharged by bottom door wagons into a hopper between the rails from which it is conveyed up one of the girders by a push-plate conveyor. The withdrawal of the coal from the heap is effected in a manner similar to that employed in the installation previously illustrated and described.

The cost of stacking the coal varies with its size, from one halfpenny to one penny per ton for coal $1\frac{1}{2}$ in. cube to 8. in. cube, and one farthing to a maximum of twopence halfpenny for the removal of the respective sizes. This difference in cost is accounted for by the fact that the small coal will run on its own account into the conveyor whilst the large coal requires some assistance. The figures are pre-war.

Stock Heap of the New York Central Railway at Dewitt.

—This is illustrated in Figs. 1031

Figs. 1031 and 1032. Stock Heap of the New York Central Railway at Dewitt.

and 1032. Through the centre line of the pile four lines of rails are laid, of which, however, only the two outer ones proceed straight through; these sidings are for the accommodation of the hopped bottom wagons which bring the coal. As may be seen from the cross section there is a V-shaped trench, into which the wagons discharge, and the coal is then taken by grab and transferred on to the pile. The bridge crane can traverse the whole circle for distributing the coal, working from one centre, the diameter being about 425 ft. The coal can, of course, be transferred by grab from the trench direct on to the tenders of engines.

A similar installation of the same railway company is at Albany Station. It might be mentioned that very similar installations could be erected square instead of round, which appears to be more economical as regards space.

Gravity Bucket Conveyor as used in Connection with a Chalk Storage Plant.—This installation, illustrated in Figs. 1033 and 1034, is used for

conveying broken chalk for cement manufacture. The material is delivered alongside in barge loads, and is discharged by two steam cranes and grabs into a double receiving hopper on the jetty. These hoppers deliver into two breakers which reduce

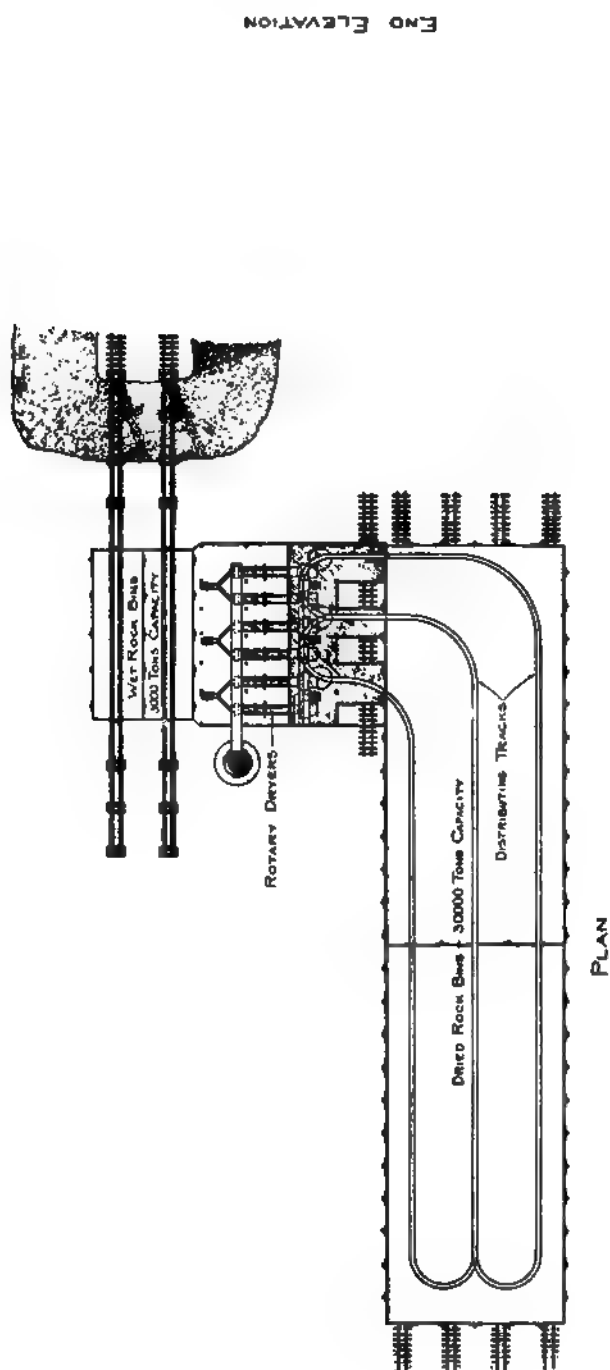


Figs. 1033 and 1034. Gravity Bucket Conveyor in Connection with Chalk-handling Plant.

the chalk to a suitable size for handling in the cement works, and it is delivered into a stock heap, in the first instance, by means of a gravity bucket conveyor. The capacity of this plant is 60 tons of broken chalk per hour.

The installation was erected by Babcock & Wilcox for Caseborne & Co., Haverton Hill-on-Tees.

Phosphate Drying and Storage Plant (Darley System).—A complete



Figs. 1035, 1036, and 1037. Phosphate Drying and Storage Plant of the
Amalgamated Phosphate Co., Chicora, Florida.

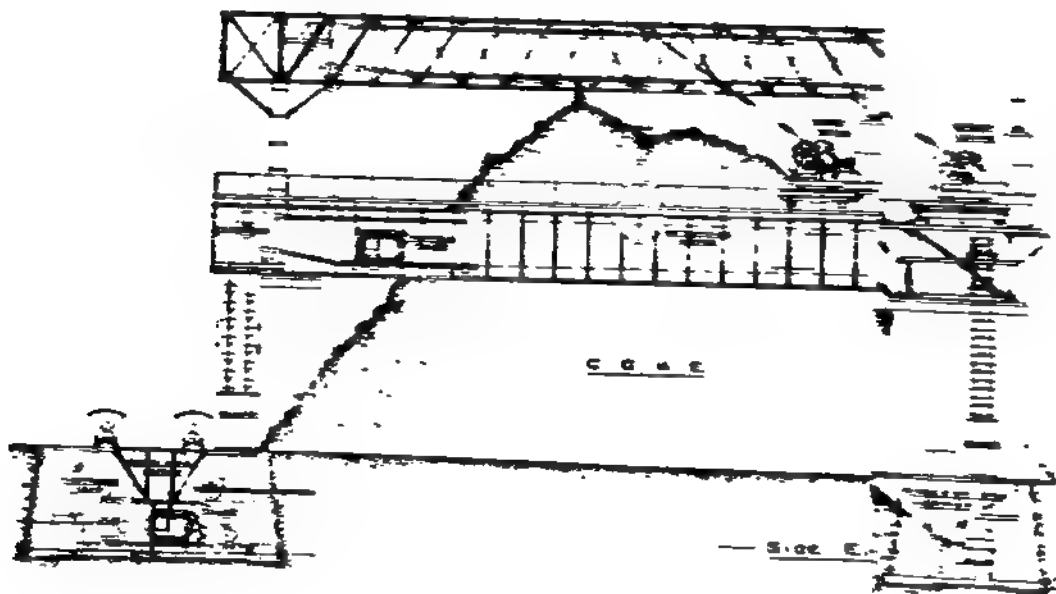
VERTICAL SECTION

END ELEVATION

PLAN

VERTICAL SECTION

Figs. 1035, 1036, and 1037. Phosphate Drying and Storage Plant of the
Amalgamated Phosphate Co., Chicora, Florida.



Figs. 1041, 1042, and 1043. Mechanically equip

See page 713.

plant of the Amalgamated Phosphate Co., of Florida, is shown in Figs. 1035, 1036, and 1037, which represent the general scheme of operation of a modern pebble phosphate plant. The trains from the mines are run over the wet rock bins of 3,000 tons capacity to a stock pile beyond. From the former the rock is drawn by three belt conveyors. The mill building between the wet and dry bins contains the elevators and oil-burning drier. The dried rock is elevated, screened, and then distributed in the 30,000 tons dry storage by means of three motor-driven cars. Standard gauge phosphate cars are run in beneath the dry bin on the four tracks and are served by the loading spouts. The installation is the design of the Guarantee Construction Co., of New York.

Mechanically Equipped Ore Stock Pile of the Cape Copper Co., Briton Ferry.—The general arrangement of an installation for handling broken ore erected by Babcock & Wilcox, Ltd., is shown in Figs. 1038, 1039, and 1040. Standard gauge railway wagons are brought to the point indicated on the elevation, and are placed on a cradle, which is tipped over into the small hoppers which supply the material direct to gyratory breakers, after which it is conducted by a shoot into hoppers, which again in turn deliver into the rotary fillers of the gravity bucket conveyor. The material is elevated to the necessary height, carried over the storage space, and delivered at any points required, forming a large heap of ore. The capacity of the conveyor is 40 tons per hour, and the ore is taken away according to the requirements of the smelting works.

Coke Storage Plant of the Glasgow Corporation at the Provan Gas-works.—This is shown in Figs. 1041, 1042, and 1043, and the process is briefly as follows: The coke is brought from the retorts in tip wagons by small locomotives, and discharged into the receiving hopper shown on the side elevation. The coke immediately passes through a regulating device into the fillers of the conveyors, and is elevated and passed horizontally by these conveyors over the heap and discharged at any points required. The wing or lower conveyors will build two outer heaps to a certain height, and the centre and higher conveyor will fill up the centre to a much greater height, forming altogether a long heap with three ridges, the centre ridge being higher than the outer ones.

Mounted on the gantries of the wing conveyors are travelling cranes, and these lift the coke from either the centre heap or from the lower wing heaps, delivering it to the hoppers which are shown in plan in connection with the wing conveyors, which latter will then carry it on to the screens shown at the extreme right of the side elevation. These screens are operated by a gas engine, and discharge the screened coke, breeze, etc., into the respective wagons set aside for this purpose.

The rate of handling of each of the conveyors is 30 tons per hour, or a combined capacity of 90 tons per hour.

The installation was erected by Babcock & Wilcox, Ltd.

Coal Storage Plant of the Indianapolis Light and Heat Co.—This installation (Fig. 1044) is unique in that provision has been made for submerging the coal under water to prevent spontaneous combustion. The plant has a total storage capacity of 13,000 tons, and provides against coal shortage due to strikes at the mines or on the railways, and to car shortage.

The plant consists of a concrete pit 300 ft. long by 100 ft. wide and 28 ft. deep. It is 18 ft. below ground level, having a 10-ft. wall rising above the ground. Below the ground the wall slopes at an angle of 45°, this being done only to reduce the cost of construction. The pit is thus 72 ft. wide by 272 ft. long at the bottom. The concrete is from 12 to 18 in. thick, and is reinforced throughout with twisted $\frac{1}{2}$ -in. square rods to withstand any pressure from water that may rise in the gravel around the pit.

Through the middle of the pit lengthwise there is a row of concrete piers placed 15 ft. centres; these support a standard gauge track on which a 15-ton Brownhoist locomotive crane travels back and forth, handling the coal on both sides with a 2-yd. coal grab, suspended on a 40-ft. boom. The crane and grab are operated by one man from his stand in the cab; the crane switching the cars on and off the trestle. The coal cars are run out on the trestle with the crane and dumped, and when the coal is

Fig. 1044. Coal Storage Plant of the Indianapolis Light and Heat Co.

required in the power house, it is loaded into cars by the crane and carried to the boilers. 40-lb. rails are embedded in the bottom of the pit, 18 in. pitch, with $\frac{1}{2}$ in. of the head standing above the surface to prevent the grab from striking the concrete.

The pit is filled with water up to the ground level, and covers 13,000 tons of coal. The water is pumped into the pit by a 4-in. centrifugal pump from the pump-house supply well, and it enters the pit at the ground level. Through the centre of the pit and beneath the trestle there is a trough 12 ft. wide and 1 ft. deep, which serves as a drainage. It is fitted with a drain pipe which carries the water to either of two manholes, one at

each end of the pit. The outlet openings are protected by gratings to prevent any coal from entering the drain pipe.

The pit was designed by Thos. A. Wynne, Vice-President of the Company, and was built under his supervision. The locomotive crane and grab were furnished by the Brown Hoisting Machinery Co., of Cleveland, Ohio.

Mechanically Equipped Salt Store.—An interesting store mechanically equipped for housing and withdrawing salt or any similar material in bulk is shown in Fig. 1045. The principal mechanical agent in this case is an electric automatic telfer system, the skips or buckets of which are used either to bring salt in or to take it out. The length of the store is 42 m., or 138 ft., and it holds 5,000 tons of salt. It is attached to a mill in which the salt is ground and the mono-rail telfers bring it on two lines *b* and *c* for warehousing, whilst line *a* is used for withdrawing the salt to the railway siding. When loading from lines *b* and *c* the self-tipping skips discharge automatically as shown. For withdrawing from line *a* the skips are filled from a loader *e* which is kept full by the portable device *f* and an electrically driven skip hoist. The device *f* consists of a scraper conveyor which travels the whole length of the store and takes the salt from the

Fig. 1045. Mechanically Equipped Salt Store.

(The dimensions are in millimetres.)

heap to the hoisting skip. The conveyor can work at any angle either as shown or it can dip down into the hopper bottom of the store and fetch the salt from there. The capacity of the mechanical installation is 60 tons per hour, two skips being used, and the driving power consumed is only 3 H.P. The plant was built by Luther, of Brunswick.

The Storing of Coal in Silos.—The most economical method of storing coal or minerals is in elevated silos or bins, a system which has been adopted for many years as far as grain and seeds are concerned, but it is only of comparatively recent years that it has been adopted for the storing of coal and minerals, more particularly on the Continent and in America.

Some establishments have found it expedient to erect extensive silo or bin systems for storing coal, and have equipped the same with complete mechanical plants.¹ Figs. 1046 to 1050 illustrate the coal store which has been used by Messrs Possehl & Co., Altona, since 1896.

This store was designed to receive coal coming by boat up the Elbe, screening it,

¹ For installations of this class, but solely for feeding boilers, see "Coal, Coke, and Ash Handling Plants for Boiler-Houses, Gasworks, etc.," page 688.

and then dispatching it either by rail for inland use, or by vehicular traffic for local consumption. Small coal is discharged from steamers, by means of a ship's elevator, of a capacity of 60 to 70 tons per hour, whilst large coal is unloaded by a crane and grab of a capacity of 40 to 50 tons per hour. The small coal which has been unloaded by the ship's elevator is stored in fifteen silos, which are hopper-bottomed, and the whole of their contents can therefore be withdrawn with a minimum of labour. Six of these fifteen silos are set apart for such coal as requires screening.

The main store contains six silos 69 ft. in height, reaching down to the level of the ground, and nine silos of a height of 50 ft. The former measure 27 ft. 6 in. by 21 ft. 6 in., and hold 1,000 tons, whilst the latter have a floor area of 27 ft. 6 in. by 28 ft. 6 in., and hold 800 tons. On the quay is an iron tower containing an elevator, and connected with the main store by two gantries.

Fig. 1046. Elevation of Coal Store, Altona.

The ship's elevator is suspended from one end of a derrick which is supported from the tower. The elevator discharges the coal on to a band conveyor which has been erected within the derrick. This band in turn discharges its load on to a second band running on the lower gantry, delivering into an automatic weighing machine, whence it slides down a shoot to the well of an inner elevator which takes it to the top of the building, and to another band conveyor which is provided with a throw-off carriage to the various silos, almost identical with a granary installation.

On the ground floor is a movable automatic weighing machine that can be brought into contact with any of the silo outlets, the coal being thus automatically withdrawn and weighed at the same time. This refers to the nine silos only. The remaining six, for coal to be screened, extend to the ground, and are connected with two band conveyors. These deliver the coal to another elevator which takes it up to the top of the building, from which it is conveyed by a band to the screening appliances, and thence into a series of smaller silos ready for loading into vehicles.

[To face page 716.]

The whole installation is driven by electricity, and when in full work only consumes 120 H.P., which is generated by a vertical engine of 150 H.P. coupled direct to the electro-motor. A similar engine, but of only 45 H.P., is held in reserve for use when only a portion of the plant is required.

In these stores great care is taken to record the temperature at regular intervals, and thermometers enclosed in iron pipes are fixed in the different silos for this purpose, as a means of guarding against spontaneous combustion.

This installation is the design of G. Luther, of Brunswick, by whom it was erected, and to whom the author is indebted for the description and illustrations given above.

In Continental ports like Hamburg, coal stores either on this or a similar system are absolutely necessary, and they are also becoming popular in all great industrial centres.

Fig. 1051. Ore-handling Plant of the Wheeling and Lake Erie Railroad, Huron.

Mechanically Equipped Ore Pile, in use by the Wheeling and Lake Erie Railroad, Huron, Ohio, and illustrated in Fig. 1051, which shows four stacking machines. They are built by the Wellman-Seaver-Morgan Co., are rope operated, and handle a Hulett automatic grab having a capacity of 5 tons of ore. They are equipped with weighing hoppers for the purpose of weighing the ore before placing it in cars for road shipment. The cantilever at the end of the machine is provided for stocking purposes, and the machine can rehandle the ore from this stock pile into weighing hoppers, to be discharged into road cars.

In addition to the foregoing, reference may be made to the following installations mentioned in other chapters:—

The Coal Loaders at the Japanese Port Miike, see page 634, the mineral silos under "Rope Haulage," see page 289, and Boiler-House Installations, page 691 and following pages. Also some examples in the chapter on "Transporters," and the Hoover & Mason Ore-handling Plant included in the chapter "Handling Raw Material in Connection with Blast-Furnaces," page 388.

CHAPTER XLII

THE WAREHOUSING OF GRAIN

Silo warehouses are intimately connected with the mechanical handling of material, as grain and seeds must be conveyed to and from silos or floor warehouses by mechanical means, and the storage of grain in elevated silos will admit of its being withdrawn by its own gravity without the aid of manual labour.

A silo warehouse has obvious advantages over a floor warehouse as far as labour saving is concerned, but it is also an undoubted fact that some grain, particularly home-grown English and other soft wheat, is better stored in floor bins, because grain stored in high silos is subjected to great pressure, which has a tendency to raise the temperature of damp wheat. If it must be stored in silos it is necessary to turn it over at frequent intervals.

The problem of how to store grain engaged the attention of the early Egyptians and of other nations of antiquity. Two distinct systems of grain storage were known to the ancients. The most primitive way was in all proba-

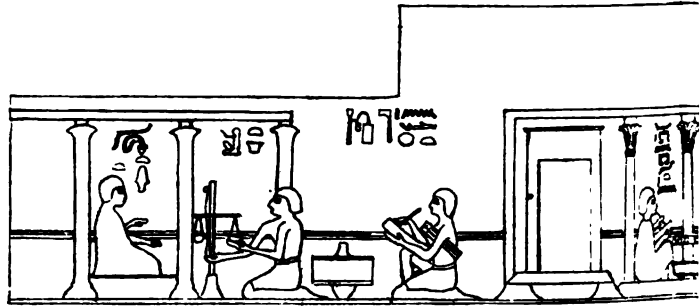


Fig. 1052. Ancient Egyptian Granary, from

bility that of storing grain in pits or excavations in the ground, the object being to keep the grain as far as possible from contact with the air. This system is still in extensive use in Turkey and other Eastern countries, an instance in point being the rock pits of Malta in which wheat is stored to-day.

The ancient Egyptian granary illustrated in Fig. 1052¹ is from a fresco in the tomb at Beni-hasan, twelfth dynasty after Lepsius, and represents the officers of the Nomarch Khnumhotep at Beni-hasan with the scribes and functionaries of the government. On the left is the treasury, where the gold and silver rendered in exchange for grain is weighed and the amount booked; in the middle is the steward of the estate, who records the amount of corn bought; and on the right the sacks are filled with grain and carried into the granary under the supervision of an official, and a clerk records the quantity deposited in the store.

Later on another and radically different system was adopted, which is still used even in this country. This method consisted in spreading grain over a floor of hard earth or concrete, and of bringing it as much as possible in contact with the atmosphere by turning the layers of grain over from time to time.

In modern days the ancient practice (which is undoubtedly the most correct one) of more or less excluding the air from stored grain has been to a great extent reverted to.

¹ From "Engineering of Antiquity" by the same author.

When new grain is brought into a granary it begins to sweat, and a rise of temperature is perceptible as well as a peculiar smell, which proves that not only does water escape but also a volatile oil. There must also be an escape of carbonic acid, for the heating of the grain can only be produced by the combustion of some of the solid substances, the starch being likely to suffer greater reduction than the small percentage of fat and protein. In order to keep the grain as nearly as possible at its right weight and in good condition it is necessary to prevent heating and only to promote evaporation of moisture artificially. This can be effected in various ways, the most common being to store the new grain in thin layers on the floor and turn it over frequently, until sufficiently conditioned to keep in silos. The method of turning wheat over in silos is less effectual, especially in the case of very new wheat, than the former method. When wheat is thus stored in thin layers the grains absorb oxygen constantly and issue carbonic acid in exchange for the oxygen taken up; they are in fact in a state of slow combustion. The hygroscopic nature of the grain is responsible for this action, as the grain absorbs moisture in a damp atmosphere and gives off moisture in a dry atmosphere. According to Muntz, the more the air is renewed the moister the grain, and the higher the temperature the greater is the issue of carbonic acid. It follows then, from the

above, that in order to store conditioned grain to the best advantage it should be kept in a dry and cool place, and the air excluded as much as possible.

Some experiments as to the keeping quality of grain were made by Mr Doyère,¹ who in 1820 constructed a silo in which grain was kept for eight years. When the French Government ordered



Fresco in the Tomb at Beni-hasan.

an investigation of the subject in 1855, Mr Doyère reported that the system of storing grain in silos greatly retarded decay, and that corn containing 21 per cent. of moisture and in contact with the air gave off 17 mg. of carbonic acid per kilogram per hour, or 408 mg. per day, while with the air excluded and at an average temperature of 68° F., the carbonic acid given off per day was only 120 mg. From this it would appear that grain exposed to air decomposes three and a half times as fast as when stored in enclosed silos. The experiments of Professor Tyndall² and of the late Mr Pasteur also bear out this conclusion.

The above, of course, refers only to the storage of grain in good and sound condition. New and damp grain containing a large percentage of moisture would not be safe from decomposition even if stored in perfectly air-tight silos. Such grain must be dried or conditioned artificially, stored in shallow bins, and turned over frequently until it is in a suitable condition for keeping.³

The origin of grain warehouses is attributed to Hungary, but these early examples

¹ "Conservation des Grains par l'Ensilage," by L. Doyère, Paris, 1862; and "Silos, Ensilage, and Silage," by Dr Manby Miles, New York, 1889.

² "Essays on the Floating Matter of the Air," Second Edition, London, 1883.

³ *Proceedings Inst. Civil Engineers*, vol. cxxvi., Paper No. 2815, by P. W. Britton, on the "Transport and Storage of Grain."

were comparatively small structures, and do not appear to have been provided with any noteworthy appliances for the mechanical handling of grain.

It is to America that the credit belongs of designing granaries capable of holding immense quantities of grain and seeds, and of equipping these warehouses with machinery to obviate as far as possible the necessity of employing manual labour in the handling of the grain. These warehouses are known in America as "Elevators."¹

The introduction of modern granaries is universally and rightly credited to the United States, and such silo warehouses have been known in America since 1846. According to a paragraph in the *Scotch American*, the designer and erector of the first American granary at Buffalo was Robert Dunbar, a native of Carnbee in Fifeshire. When a youth he was taken by his parents to Canada, where he became a mechanical engineer in 1834, and took up his residence in Buffalo, where he remained until his death at the age of seventy-eight, in October 1890. He was one of the originators of the Eagle Ironworks, and designer and architect of nearly all the grain elevators at Buffalo, and also many others. The first silo warehouse of any great capacity was built in New York in the beginning of 1880; since then, large installations have been erected at all the most important grain producing centres, as well as at the points where grain is exported.

One of the most valuable features of the American silo system is this, that it enables the agriculturist to store his grain cheaply under the best conditions, and to hold it until the market is favourable for sale. He can also mortgage his grain while he is waiting for a fair price. In America this system has been carried out on an enormous scale. A holder can store his grain in a granary, say at Chicago, and can withdraw grain of a similar grade from some other warehouse, say at New York. In fact the grain trade there is carried on somewhat after the manner of the clearing house in the money market. Comparing the floor system with the silo system for the storing of grain, it may be mentioned that where silos are applicable the same capital outlay will provide a granary of the latter type which will accommodate twice as much wheat as one on the floor system.

Silos, their Shape and their Construction.—Silos may be either square, circular, or hexagonal, and may be built of wood, brick, concrete, iron, or a combination of the two latter—reinforced concrete. The choice of material depends to some extent upon climatic conditions. The most suitable material for square bins is wood, for circular bins iron, and for hexagonal bins brickwork or concrete. Circular silos are the strongest, but are less economic in space than the other two forms. A large number of circular iron silos are used in America, the space between four large bins frequently being occupied by a smaller one.

Wood,² as a material for building silos, has the advantage of being light, strong, inexpensive, a non-conductor of heat and hygroscopic. It has also the further advantage of yielding to an unequal pressure or to a possible settlement of the structure. One of the most useful forms of construction known in the early American granaries, but now obsolete, was "cribwork," which consists of flat strips of wood nailed one on top of the other, and overlapping each other at the corners, so that alternately a longitudinal and a transverse batten extend past the corners. Short pieces of timber are nailed down on the spaces forming alternate gaps, so that the whole silo wall is solid to the end. This

¹ To avoid misunderstanding, the term "elevator" (which is in America largely applied to these warehouses) has not been adopted in this book, as in this country the word is exclusively used with reference to ordinary elevating machinery and not to granary buildings.

² Paper by Mr P. W. Britton on the "Transport and Storage of Grain," also paper by Mr J. Whitaker, A.M.Inst.C.E., on "Silo Granaries for Modern Flour Mills."

is undoubtedly a strong form of bin, but it has certain disadvantages. The planks are liable to dry-rot and cannot be renewed except with great difficulty.

Bricks or cement are suitable materials for the construction of silos, as they are bad heat conductors; they are, however, lacking in hygroscopic properties. The drawbacks to the use of such material are—its weight, the consequent necessity for stronger foundations, and the need for making the divisions thicker than when using wood.

Fig. 1033. Collapse of End Wall of Silos at Isleworth.

Iron has the distinct advantage that the silo walls can be thinner than in the case of any other material, but its non-absorbent nature, and the fact that it is a good conductor of heat is detrimental, as it transmits to the grain the change of temperature.

Ferro-Concrete is the material most largely used at the present day. If well constructed, no detriment will be caused to the structure through uneven expansion of the material. The first type was probably the Monier, followed by the Hennebique, and constructed of an iron or steel framework filled in with concrete, whilst the most modern construction consists of steel rods embedded in cement.

In the case of silo walls constructed of brickwork, these should be built in cement

and not used until they are thoroughly set, or better still, hoop iron should be built in, at least at the end walls. Fig. 1053 shows the results of non-observance of this rule. The illustration represents the collapse of the end wall of a silo warehouse at Isleworth on the Thames. The brickwork of the wall and the grain contained in the five end silos were all deposited on the adjacent ground.

Granaries at the Liverpool Docks.¹—These granaries were probably the first of any note to be erected in this country fitted with mechanical appliances for handling grain, and although they are not silo warehouses, they are here described on account of their historic interest.

In 1868, to meet a want that had been long felt in the port of Liverpool, there were erected, for the storing and conditioning of grain, large blocks of warehouses fitted with mechanical appliances designed by and executed under the supervision of G. F. Lyster, the docks engineer. Although erected for this particular object, the warehouses were at the same time so designed and constructed that they could be used as ordinary goods warehouses, a large portion of the warehouse plant being available for the handling of general goods. The plant of these warehouses is designed for loading and discharging grain in bulk or in bags, also for transporting grain into different parts of the building and for ventilating it.

The largest vessels can lie alongside, and can be discharged either directly on to the quay, or their cargo can be conveyed to the top of the warehouses or to any of the floors. Proper accommodation for rail and road traffic is provided, and goods are discharged or loaded direct from or into wagons or carts. The warehouses on the Liverpool side are situated at the Waterloo Docks, and contain an aggregate storage area of 11½ acres, including the quay

Fig. 1054. Transverse Section through Portion of Liverpool Dock Granaries.

floor. Those on the Birkenhead side are erected on the margin of the great float, and have an area of 11 acres.

The warehouse plant is similar in principle and construction in both warehouses.

The dock around which the blocks of warehouses on the Liverpool side of the river are situated is 570 ft. long, 230 ft. broad at one end, and 180 ft. at the other. Three sides of the dock are occupied by separate blocks of warehouses, connected by gantries. The blocks on the east and on the west sides are 650 ft. long and 70 ft. wide, while the block at the north end is the same width and 185 ft. long. Each block contains five stories, as shown in the transverse section (Fig. 1054). Above the top or fifth storage floor, and partly in the roof, some of the machinery is erected, while below the quay level are wells and arched subways to receive machinery. There are five discharging berths for large vessels.

¹ From a paper by Percy Westmacott, *Proceedings Inst. Mechanical Engineers*, August 1869.

The principal operations to be effected by the aid of machinery were as follows :—

Discharging grain in bulk from vessels or small craft directly on to the quay; discharging ordinary merchandise direct on to the quay, or carrying it to any floor of the warehouse, and loading outward-bound vessels; lifting and lowering sacks, bags, and other merchandise on lifts and hoists to or from any floor; elevating, screening, weighing, and distributing grain, and conveying it to or from all parts of the warehouses to any other part and back again as required for conditioning damp or heated grain.

The best means of effecting these operations were the subject of much consideration and of many and costly experiments. Ultimately it was decided that a hydraulic system of power distribution best met the requirements of the case, electric driving not having been thought of at that time. As the result of experiments, band conveyors were, for the first time, adopted for transporting grain horizontally from one part of the warehouse to another.

In order to save labour in spreading the grain over the floors of the warehouses, and

Fig. 1055. Grain Receiving and Distributing at the Liverpool Dock Granaries.

also to condition it by ventilation, a fan with a scattering action was tried with success as shown at *n* in Fig. 1054. This fan is placed 9 ft. 6 in. above the floor, and at its usual speed of 250 revs. per minute deposits the grain over an area of 45 ft. in diameter.

Five hydraulic cranes for discharging vessels are fixed in towers specially constructed in the warehouses, one of which is shown at *o* in Fig. 1054. These cranes are arranged for raising grain in skips containing 21 cwt. of bulk, at a maximum rate of 50 tons per hour. The hopper *p* (Fig. 1055) into which the grain is dropped from the skip holds about 8 tons of grain, and from this hopper it is diverted into two streams, and allowed to flow through spouts fitted with regulators on to two 18-in. inclined bands *q*. The construction of the elevators (Fig. 1054) for raising the grain from the bottom to the top of the warehouses is shown to a larger scale in Fig. 1056. The wrought iron skip *w*, capable of holding about 1 ton of grain, is slung from the lifting chain by an arrangement of bars and levers provided with guiding rollers running between upright timbers, which are so arranged that on arriving at the top the bucket tips over and discharges the grain into the top hopper *v*. This hopper delivers the grain upon the same inclined cross bands *q* that convey the grain from the outer crane hopper *p*. The bottom hopper

x feeding the elevator is made in two sections, the upper of which, protected by a grating, receives the bulk of the grain.

The clear aggregate storage area of all the floors, except quay and silo spaces, is 48,918 sq. yds., and at 4 qrs. per yard would give a storage capacity for say 196,000 qrs. of grain. There are six silos constructed of bricks and capable of containing 3,500 qrs., the total storage thus being 199,500 qrs.

Granaries at Braila, Galatz, and Constanza, Roumania.—Amongst the first silo warehouses of any great capacity that were erected in Europe for the storage of grain were the silo warehouses at Braila and Galatz. Roumania is essentially a

grain-producing country, and her prosperity largely depends on her exports of grain and seeds, her chief agricultural products being maize, wheat, barley, rye, and oil seeds.

Late in the eighties the Roumanian Government realised the importance of erecting modern granaries at the two chief ports, Braila and Galatz, and the sum of 21,500,000 francs was allotted for that purpose. The credit of designing these two great granaries, the general plan of which, by the way, is practically identical, belongs to Mr H. Saligny, a high official of the Roumanian State railways. The entire mechanical plant of these two warehouses was supplied and erected by George Luther, of Brunswick, the contract being signed in 1887.

Approximately half the exports from Roumania go by steamer down the Danube and through the Mediterranean. Although Braila and Galatz are not exactly seaports, being both situated on the Lower Danube, yet they are accessible to sea-going steamers. As it is a ten hours' run from the Black Sea to Braila, a further granary at Constanza was contemplated, which was eventually opened to traffic in 1910. Such a step was the more

Fig. 1056. Grain-Receiving Elevator at the Liverpool Docks Granary.

essential, seeing that at the rate at which the traffic increased, these two granaries soon proved inadequate.

The granaries of Braila and Galatz superseded a certain number of private granaries which existed at both Braila and Galatz. These were, however, one and all situated at some distance from the quays, and lacked modern grain-handling machinery. In those days the loading of ships with grain was a cumbrous and expensive process.

The Granary Buildings.—The marshy nature of the banks of the Danube precluded the building of the granaries on the river bank. It was therefore decided to excavate, both at Braila and Galatz, a basin 1,640 ft. long by 400 ft. wide, and to erect the granaries on the quay wall of these basins. In building both these silo warehouses provision was made for doubling the installation at some future time should this be desirable.

Although these silos were built at some distance from the actual river bank, it

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was found necessary to erect them (as well as the quay walls) for their whole length of 1,640 ft. on piles.

The granaries with their accessories are illustrated in Figs. 1057, 1058, and 1059, which include a small scale ground plan and two cross sections. Figs. 1060, 1061, and 1062 give, to a larger scale, the plan of the granaries in longitudinal and cross sections. Figs. 1063 to 1067 show plan and four elevations of the engine and boiler houses.

The illustrations show in cross section a tunnel of considerable dimensions for the accommodation of band conveyors. Besides these there are along the quay walls, at intervals of 23 ft., fifteen well-like receptacles of a depth of 20 ft. and a diameter of 6 ft. These are connected with the above-mentioned tunnel by shoots. (The use of this tunnel will be more fully described later on.) There are also two transverse tunnels extending to the ends of the silo building. One of the sections shows these tunnels, which are all intended for the reception of band conveyors.

The silo-house lies back at a distance of 115 ft. from the quay wall, the ground space occupied being 394 ft. long by 92 ft. wide. The height of the building to the eaves is 60 ft.

The foundations of the granaries were laid on a system of more than 5,000 piles. In addition to this, the foundations of the building extend to a depth of 23 ft. into the ground. Immediately on top of the piles is a layer of concrete which brings the level of the basement to 17 ft. 6 in. below the outer ground level. Both ends of the building terminate in two higher parts to accommodate the staircases, elevators, automatic scales, and driving gears. The centre portion of the building which encloses the silos is covered by a roof with large skylights. The whole of the basement is intersected by tunnels which run the entire length of the building. The tunnels are each 10 ft. high, and are intercepted at three points by cross tunnels connecting the nine transverse silos. Above these tunnels rise the silos themselves. They are 55 ft. high, and of a hexagonal section.

The building materials used for these silos were Monier plates, which consist of cement slabs with wire insertion or foundation. These insertions project at the ends of the slabs, and when the latter are set in position, corner cavities are formed into which these ends are protruded. The cavities are then filled up with semi-liquid cement, which, when hardened, forms a solid block. The silos in both granaries are made in two sizes, about one-fourth of the area being occupied by cells measuring 8 ft. 2 in. across, whilst the remaining cells have a measurement of 11 ft. 6 in. Between the silos and the northern annexe, in which the stairs, etc., are situated, is an elaborate grain-cleaning plant.

Further north still, in a separate building some distance away from the actual silo-house, are the engine and boiler houses, the arrangement of which will be seen from Figs. 1063 to 1067. The five boilers and the 500 H.P. engines were installed with a view to the future extension of the plant. The engines are of the compound condensing type, and run at 60 revs. per minute. The flywheel has grooves for twenty 2-in. ropes which distribute the power for the plant.

The Mechanical Equipment of the Granaries.—The whole of the grain-handling plant with which the granaries are equipped is designed as much for the reception as for the discharge of grain.

At the edge of the quay are rails with a gauge of 11 ft. 6 in., upon which run two mechanical unloading appliances. The first consists of a telescopic elevator which can be lowered into ships or barges, and which raises the grain and delivers it to one of the two band conveyors at the head of the apparatus, each of which in its turn feeds automatic weighing machines with an hourly capacity of 75 tons. These weighing machines either discharge their load through a manhole in the ground on to a band conveyor

which runs in the tunnel parallel to the quay walls, or the grain is again elevated by means of a second elevator in a slanting position, which delivers the grain at a sufficient height to render easy the loading of railway trucks on the siding which runs parallel with the quay (see Figs. 1058 and 1059). The driving power is provided by a pair of vertical compound engines of 35 H.P., the steam being generated by two vertical tubular boilers. The boilers are fed by two water tanks. A turning gear, which can be driven from the engine or by hand, will so reverse the position of the whole apparatus that the portion which overhangs the water can be turned inland, or vice versa. The whole of the apparatus is mounted on a platform provided with six wheels, the end ones of which are geared to the shafting and move the whole of the unloading plant by power. The unloading capacity is 150 tons of grain per hour.

For the purpose of loading ships the telescopic elevator is turned towards the granary, when it can be lowered into any of the fifteen grain wells which are constantly fed with grain by the longitudinal and either of the two transverse bands coming from the silos. The action is then almost identical with that of loading the grain from the boat to the railway trucks, with the exception that the sleeve from which the grain is delivered is lowered down into the ship's hold instead of into the grain wells. The second loading device is exclusively for loading ships with grain, and is therefore not reversible. It is built on a similar carriage to the last-named apparatus, and is provided with two boilers and a 35 H.P. engine, precisely as the last mentioned. There are two vertical elevators of the ordinary type, one of which fits exactly into the grain wells, into which it can be lowered, whilst the second elevator receives the grain from the first after it has passed through two weighing machines, whereupon it is finally discharged down the telescopic shoot into the ship's hold.

The grain, which is received from barges and other vessels, and is intended to be stored in the silos, is spouted to the longitudinal band conveyor, of which the upper strand runs from north to south, while the lower strand runs in an opposite direction. The strands are so far apart that both can be simultaneously used for conveying. Thus the grain can be taken from the barges either to the northern or southern cross conveyor, by spouting either to the lower or to the upper run of a longitudinal band conveyor. In the same way grain may be taken from either end of the silos to any one of the fifteen grain wells, as may be most convenient for the loading of ships moored at either end of the quay. Grain is distributed to the silos as soon as it is received by any one of the three band conveyors, while for discharging there are three similar bands in three of the nine tunnels below the silos.

The northern section of the receiving machinery, which is shown in the cross section (Fig. 1058), contains four elevators in iron casings, the diameter of the internal pulleys being 4 ft. by 28 in. The northern cross conveyor terminates in the basement of this annexe; here, too, terminates the second cross conveyor, by means of which the grain is removed from one silo to another for ventilating purposes. On the upper floor in this same annexe is a further cross band conveyor, which distributes the grain raised by the elevators to any of the longitudinal bands which lead to the silos. There are also two short longitudinal bands for feeding the grain to the wheat-cleaning department. The same annexe contains two centrifugal pumps for the purpose of removing any water which may find its way through the foundations. Provision is also made for sacking off the impurities removed from the grain in the adjoining cleaning department. Some of the motive power is also distributed from this section, the main shaft receiving 270 H.P. from the engine-house, giving off its power to the third floor above the ground by means of two wire ropes. This is the whole of the power with the exception of the 80 H.P.

which is required for driving the grain-cleaning plant, and which is transmitted to this department by a separate rope. A portion of the 270 H.P. is conveyed from the main shaft just mentioned to the other end by means of another steel wire rope.

The granary at Constanza, the foundation of which was laid in 1896, was opened to traffic in 1910, and consists of two imposing piles, close together, with sufficient space to erect two, possibly three, more; each of the two is divided into 255 silos, holding 63,100 qrs., together 227,000 qrs. or 70,000 tons. The general arrangement is on similar lines to that of the granaries at Braila and Galatz. An iron gantry about 600 yds. long was erected at the quay wall to facilitate loading along the whole of its length, and band conveyors carry the grain from the granaries to this gantry, in which are other band conveyors which also run along the whole of its length, and which have provision for throwing off the grain at fixed distances; connections from these can be made by portable telescopic shoots to ships lying alongside, while the swivelling shoots which deliver the grain from the band conveyor project obliquely downward from this gantry. The area covered by each of the granaries is approximately 3,000 sq. yds., and the height from the quay level to the top of the highest part is about 155 ft. The conveyors and elevators of the installation are capable of handling 150 tons per hour, or 300 tons for the two granaries, which can deliver their grain into one and the same ship; there is in addition the grain which can be loaded without passing through the silos. Five vessels can be loaded simultaneously, and it is said that a double row, *i.e.*, ten, can be loaded at the same time, if necessary.

The granary at Braila contains 334 silos which have a capacity of 377,560 hl. (129,879 qrs.), whilst that at Galatz contains the same number of silos with a capacity of 346,080 hl. (119,050 qrs.).

Granaries at Breslau.—The illustrations, Figs. 1068 to 1071, show a longitudinal section through the whole of the granary, as well as three cross sections. The cleaning plant is installed in the centre of the building, grain being stored on either side. One wing is provided with silos, the other is used for storing grain on the floors.

Grain is received at the centre of the building exactly in front of the cleaning department, either by rail, or by means of one of two barge elevators. After being elevated to the top of the building, it may either be passed through the cleaning plant, or it may be carried by a band conveyor to either of the wings to be stored. The top band conveyors are fitted with throw-off carriages, so that any part of the granary can readily be served. The lower strands of these band conveyors are also used for withdrawing grain and feeding the cleaning plant, which consists of a warehouse separator with a full system of cockle and barley cylinders for eliminating any seeds from the grain, which, when received, and prior to its delivery to either of the two elevators, is passed through an automatic weighing machine. There are also further automatic weighers through which the grain is passed before being sacked.

The barges can be brought alongside right under the receiving elevator, where they are discharged, as shown in the illustration, Fig. 1071. This elevator is 36 ft. long from centre to centre, and has a capacity of 40 tons per hour. It is so arranged that it can be lowered or raised to the level of the grain in the barges, and can also adjust itself to the water level of the river. The delivery of the elevator always takes place at the same spot. From this point the grain is removed through a spout to a second elevator, which in turn delivers it to the automatic grain scale, whence it passes through a grain-cleaning machine known as a warehouse separator, where it is again spouted to the elevator shown in the centre of the grain warehouse.

The receiving grain elevator can be raised or lowered by a small winch. The

elevator itself is one of the chain type, with sprocket wheels at top and bottom, the framing being substantially constructed of angle iron and timber.

Fig. 1072. Spencer's Granary Floor Spouting.

The wheat elevated from the barge is, of course, in an unclean condition; the weighing machine, however, keeps an accurate record of all material, dirty or otherwise, which passes in a continuous stream through the different elevators to the cleaning

machines. The grain, as it passes from these latter, is by no means perfectly clean, but all such gross impurities as string, sticks, or any large foreign matters, as well as a certain amount of dust, are eliminated in this preliminary process.

Spencer's Granary Floor Spouting.—A method of distributing grain in floor warehouses has been perfected by Spencer & Co., Ltd., of Melksham.

There appears to be a growing tendency to store certain kinds of grain, especially



Fig. 1073. Simplest Form of Grain-distributing Valve.

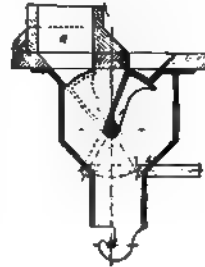


Fig. 1074. Alternative Form of Grain-distributing Valve.

home-grown wheat, in floor warehouses instead of in silos. Fig. 1072 shows two devices adopted by Messrs Spencer to deposit the grain in a series of floor bins above each other, and to withdraw the grain from one bin to another for the purpose of turning it over. In the section on the left-hand side this system is shown as applied to floor bins with level floors, whilst the right-hand section shows an installation for floor bins with hoppers

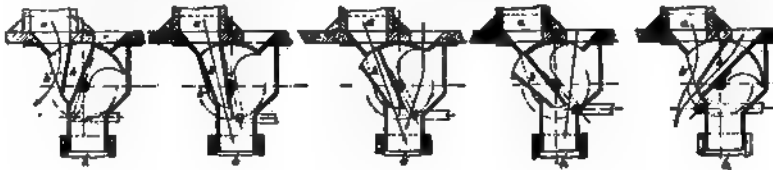


Fig. 1075. Grain-distributing Valves in Different Positions.

Fig. 1076. Grain-distributing Valves in Different Positions.

bottoms. The latter are preferable, as they require no trimming whatever. The drawing will be readily understood by the aid of its descriptive legends.

System of Distributing Grain between the Floors of a Granary.—This is in use on the Continent, and the valves used for this purpose are shown in Figs. 1073 to 1076.

The working of these valves, which can be controlled from the basement by chains, may be seen from the illustrations. In Fig. 1073 the simplest form of valve is shown in two views; *a* is the connecting spout through which grain may be taken, *via* the

main spout, to any desired floor beneath, whilst *b* shows the mouth of the spout from which grain falls from a bin on any one floor into the bin lying immediately underneath on the floor below. If there is no necessity for taking grain straight away through one floor, the valve provided is as shown in Fig. 1074.

If the valve be placed in a central position, the grain on the floor below can be mixed with grain from any floor above through the conduit *a*; and if it be desired to mix grain from several floors, conduit *b* is provided as part of the valve. From the different positions of the valves in Fig. 1075, the direction in which the grain to be mixed must flow can easily be seen.

If it be desired to let grain through from one bin to its fellow on the floor below, and at the same time to carry grain to delivery spout *a* in a downward direction, one of

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Fig. 1077. Silo Warehouse at the London and India Docks.

the walls of conduit *b* is bent back, and takes a cup-like shape. This cup is open at the top with an outlet *l* at its lower end (see Fig. 1076).

Silo Warehouse at the London and India Docks.—This granary, illustrated in Fig. 1077, has a total capacity of about 25,000 qrs., and is built on the American crib-work system, with an interlaced timber structure resting on iron columns. The walls are covered with an external steel casing. The total height of the building is over 100 ft.; the silos are fifty-six in number, each about 10 ft. square by 50 ft. deep.

On the right of the picture is an intake plant about 100 ft. from the granary. This has a capacity of 100 tons of wheat per hour, and includes appliances by which the grain is automatically weighed into the bins. There are six automatic grain scales, each weighing the contents of one sack at a time, on the sacking-off platform, which has an arrangement whereby it is always kept at the correct level for delivering to barges.

The main delivery floor of the granary is about 8 ft. above ground and is level with the tops of railway trucks. On this floor are a number of portable automatic

weighing machines which can be placed beneath any bin, and so deliver to railway trucks or vans.

The whole of the plant is driven by electro-motors, one for each machine. There are two main elevators, two bands conveying at the top of the silos and two underneath, so that grain may be taken from barges, delivered to silos, turned over from one conveyor to another, or delivered to the weigh-out house and main delivery platform simultaneously.

This installation was erected by Spencer & Co., Ltd., of Melksham.

The First Grain Warehouse, Manchester Docks.—The general arrangement of this important warehouse is shown in Figs. 1078 and 1079, one being a general plan and the other a perspective view. This granary, which is 448 ft. long by 80 ft. wide, was erected in 1898, the whole of the superstructures being built of wood on the American system with an external casing of brickwork and tiles.

The building has a storage capacity of 40,000 tons of grain. There are 226 bins, varying in capacity from 37 to 300 tons each.

The granary stands at a distance of about 340 ft. from the side of the dock, where the tower and ship elevator are situated, being connected with the main building by a trolley with band conveyor. The elevator is capable of raising some 350 tons of grain per hour from the hold of a vessel containing a full cargo of grain. Arrangements are made in the tower by means of which the grain is weighed whilst being conveyed from vessel to elevator, the weight being there checked by both the representatives of the vessel and the owner of the grain. After the grain has been conveyed into the main building, it is again lifted to the top of the central tower of that building, and thence distributed to the various bins.

Appliances for the delivery of grain upon an extensive scale into railway trucks, and vans and lorries, barges and coasting vessels (either in bags or in bulk), have been provided, and can be worked concurrently.

In addition to the ordinary method of discharging grain by means of ship elevators, the use of Duckham's pneumatic elevators has been provided, which is employed *inter alia* in dealing with small parcels of grain, and with grain stored in positions which cannot be reached by the ordinary ship elevator.

Power is supplied for the working of the elevator and the various band conveyors to the main building, as well as leading thereto and therefrom, by two sets of horizontal Corliss compound engines of 500 H.P., fed with steam by two Galloway boilers working at 100 lb. pressure.

The power for the pneumatic apparatus is provided by two sets of triple-expansion vertical engines of 600 H.P., supplied with steam by three boilers working at a pressure of 160 lb. per square inch.

The following operations can be performed simultaneously at the warehouse:—

1. Discharging from vessels alongside at the rate of 350 tons per hour.
2. Weighing in tower at the water's edge.
3. Conveying and distributing into any of the 226 bins.
4. Moving grain about for changing bins or for delivery, and weighing in bulk at a rate of 500 tons per hour.
5. Sacking grain, weighing and loading sacks into forty railway wagons and ten carts.
6. Conveying into barges or coasters at the rate of 150 tons per hour if in bulk, or 300 sacks per hour if sacked.

The author is indebted to Mr W. H. Hunter for the illustrations which accompany the above description.

The Transit Silos on the Thames.—These form a most interesting group of

Fig. 1079. General View of Manchester Ship Canal Grainary.

installations. Although only used as transit silos, they are silos in the fullest sense of the word, and therefore deserve to be mentioned in this chapter. They were built for the old London Grain Elevator Co. by Spencer & Co., Ltd., and are situated on the south side of the Victoria Docks. They consist of four complete and independent installations. The area of this portion of the Victoria Docks is 50 acres, half of which is water, and the other half land. The space is oblong in shape, and is shown in the plan, Fig. 1080. At each end three peninsulas project into the water, thus forming four docks of an area of 2 acres each for the accommodation of the barges. The water in these berths is of sufficient depth to accommodate all ships which can enter the Victoria Docks, so that the largest ships can have their cargo discharged, weighed, or transported into smaller up-river barges, to railway trucks, or into the large flour mills that have been built there. All these operations can be carried on under cover, and are therefore quite independent of the weather. The four transit silos, two of which are shown in the illustrations, Figs. 1081 and 1082 (which also give explanatory notes), are situated on the south-west and north-west peninsulas, leaving one peninsula for the probable further extension. Each silo-house marked c on the drawing is divided into nine bins or silos, eight of which are used for storage purposes only, whilst the middle space is used for the accommodation of staircases, elevators, etc. Each of the eight silos is 12 ft. square by 80 ft. deep, and has a capacity of 1,000 qrs. of grain.

The silos are erected on a massive cast-iron tank forming a cellar, which rests upon a concrete foundation 6 ft. in thickness, the bottom of this tank being 30 ft. below the water level. They are built on the interlaced timber system which has already been described, being formed of "battens" nailed on top of each other, the pieces interlacing. The silo bottoms are so constructed that there are no joins in the corners, thus dispensing with rivets at these points, as they are apt to obstruct the flow of the material, and prevent the silos from emptying completely. These silos are supported on rolled steel girders which rest on cast-iron columns. The outside of the granary is covered with corrugated iron, and the roof is covered in a similar manner. The silos are about 100 ft. high, and carry a substantial iron roof which also covers two gas engines for driving the three delivery elevators, one of a capacity of 120 tons per hour, and two of a capacity of 100 tons each per hour. There is no occasion for conveyors, as the elevators which rise above the tops of the silos can readily deposit the grain into any one of them.

In connection with each silo is a barge elevator having a capacity of 120 tons per hour, which is driven by a separate gas engine. This outer barge or receiving elevator discharges its load into the elevator well inside the warehouse. Each delivery elevator leads to a discharge shed in which the grain is weighed. In this shed is a large receiving hopper (marked *e* in the illustration), below which are six automatic weighing machines all fed from this hopper. After weighing, each machine discharges itself automatically into sacks, which are then ready to be loaded into barges or railway trucks. The four installations are all on exactly the same lines as the one described. Each pair of granaries is provided with one common sack conveyor band which is 308 ft. in length, so that the full sacks can be carried to the railway trucks as soon as they can be got ready by twelve men in connection with each weighing shed. There is one gas engine for driving each of the two sack bands. These sack bands are so arranged that the speed can be either slow, to take sacks, or it may be higher for the purpose of conveying grain in bulk for loading barges or bulk grain cars.

The silos are generally fed by a fleet of twenty-six of Philip's patent self-discharging lighters.¹ These lighters are charged from ocean-going steamers at Tilbury, and towed by

¹ See page 517.

special steam tugs to the transit silos. Previous to the installation of these important granaries the grain had to be unloaded and weighed by means of a floating hopper which

Figs. 1080 to 1082. Transit Silos at the Victoria Docks.

was exposed to all weathers, and the motion of the unloading elevator was not conducive to accurate weighing; but with the new machinery it is now possible to discharge at the rate of 100 tons of grain per hour from each hatch by means of the derrick elevator

described on page 502. And whereas the lightermen had formerly to be at work night and day, it is now possible to make all deliveries to receivers by daylight. The arrange-

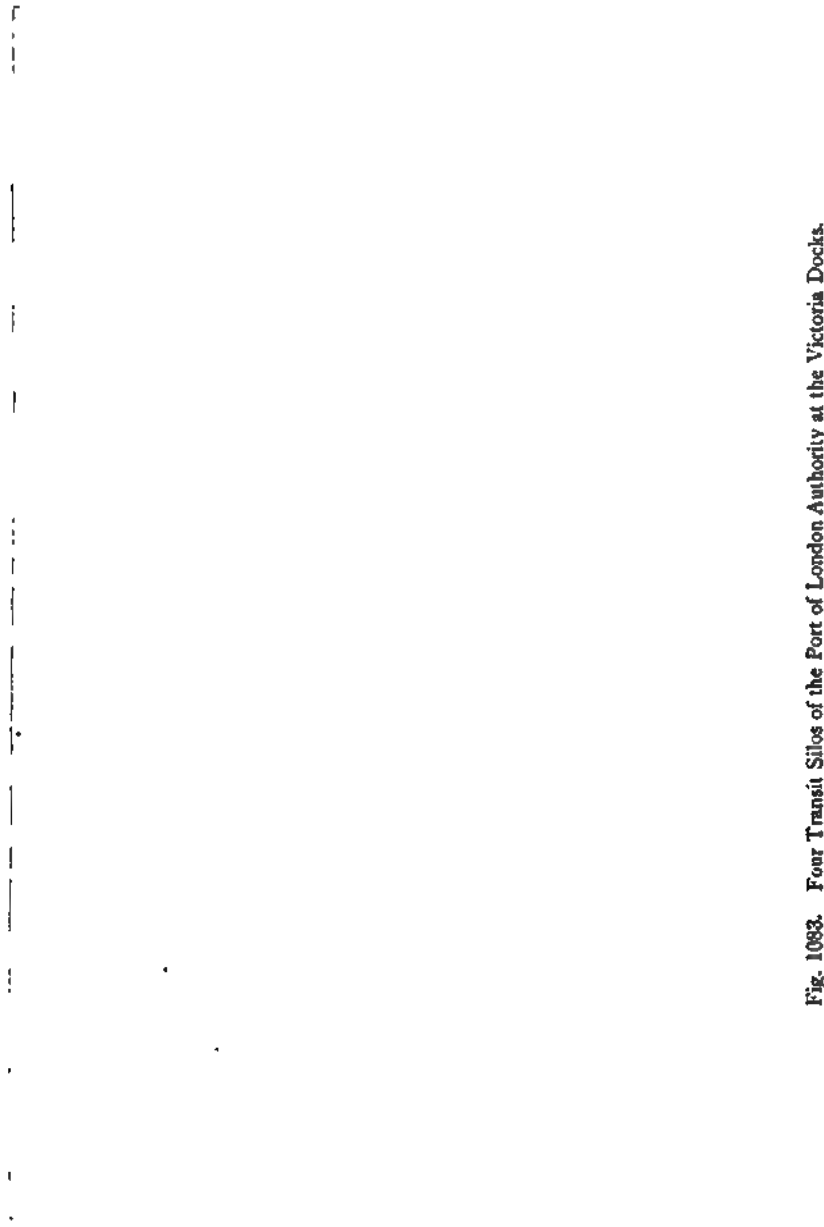


Fig. 1083. Four Transit Silos of the Port of London Authority at the Victoria Docks.

ments are so perfect that the grain which is loaded at Tilbury into the lighters can be delivered to rail or private craft from the transit silos in six hours. The whole installation is driven by fourteen gas engines, three being employed for each silo-house and two for the sack bands. The gas engine for the intake or barge elevator is one of 20 H.P., the

one for the inside elevator 36 H.P., the one for turning over and delivering the grain 28 H.P., and the two for the sack bands 15 H.P. each. The actual power consumed is, however, less than this. Fig. 1083 gives a photographic view.

Granary at the Avonmouth Dock.¹—An interesting plant is the granary of the Royal Edward Dock, Avonmouth, Bristol. Grain is imported in very large quantities at Bristol, and the port has always been famous for the rapid discharge of this commodity. With this additional storage capacity, combined with the very latest machinery, this western port claims to be one of the first in discharging, storing, and distributing grain.

The fine building consists of nine floors measuring 222 ft. long by 72 ft. wide, and is on the east side of the dock in the rear of No. 2 Import Shed. The structure is of ferro-concrete (Hennebique system), and rises 89 ft. from the ground level to the roof parapet. In the foundations ferro-concrete piles 14 in. square and averaging 50 ft. in length were used. The granary will hold 50,000 qrs. of grain and is capable of extension when necessary. One end is occupied by elevators and weighing machines; the middle portion of the building is divided into silos 11 ft. 9 in. by 10 ft. in the clear and 50 ft. deep. The lower end of each silo is hopped and has the usual valve by which the grain is withdrawn. The other end of the building is designed as a floor granary.

On both sides of the granary are double track railway sidings over which roof coverings are constructed. The sides of the building facing these tracks are open to a height of about 12 ft. from the ground level.

The interesting and complex equipment for handling the grain by conveyors and elevators was supplied by the New Conveyor Co., of Smethwick. They are designed to carry grain at the rate of 400 tons per hour continuously from the wharf side to the granary, where it is automatically weighed, checked, and deposited in the various silos or upon the floors. This result is attained by the adoption of subways, without in any way obstructing the traffic at the wharf or in the neighbouring roads and railway sidings.

In the rear of the dock wall is a tunnel for the conveying bands. The width of this tunnel, which extends along the entire length of the dock wall on the east side and is returned thence at an angle of 90° to the new granary, varies according to the number of belts in a particular position. Abreast of No. 1 transit shed at the south end of the dock, the tunnel is 9 ft. wide in the clear and 7 ft. in height. At No. 2 shed it is 16 ft. wide and increases to a maximum of 45 ft. in width near the granary itself. The total length of the tunnel is about 1,740 ft. It is constructed throughout of ferro-concrete.

The conveyors are of the endless-band type, arranged in parallel lines in the tunnel. The bands, which are of cotton and india-rubber, are 22 in. wide, and are capable of sustaining a tensile stress of 800 lb. per inch of width. The idlers are about 6 ft. apart, and automatic tension gears are provided. The speed of the band is 650 ft. per minute, which speed represents 100 tons of grain carried per band per hour. The grain is, in the first instance, elevated and discharged from the ship into portable hoppers on the wharf. These hoppers fit over cast-iron shoots built into the wharf and communicating with the above-mentioned tunnel. Valves are provided in the hoppers, and on the lower ends of the wharf shoots for the proper regulation of the grain as it is discharged into the shoots and upon the conveyor bands.

The first section of the tunnel contains two conveyor bands 570 ft. long between

¹ *The Engineer*, 10th July 1908 and 25th September 1909.

terminals, and each band is fitted with portable distributing shoots, which receive the grain from the wharf shoots, which are spaced about 52 ft. apart along the dock side, enabling the bands to receive grain practically at any part of their length. The wharf shoots are covered by a special water-tight cover when not in use. The two conveyors in the first section of the tunnel are continuous throughout the section, forming with the addition of two other bands four complete and independent conveyors, each having its own 30 B.H.P. motor, tension gear, and receiving shoots. These four conveyors are 750 ft. long between terminals, and are broken at about 200 ft. from the forward end for convenience in driving, each motor being arranged to drive approximately an equal length of band. The two conveyors in the first section of the tunnel are disposed at the dock side of the tunnel, and can be fed directly from the wharf shoots. In the second section the third and fourth conveyors are fed indirectly from the wharf shoots by means of short cross conveyors mounted on travelling carriages above the main bands. These carriages traverse the whole length of the second section of the tunnel, the cross band receiving grain from any one of the wharf shoots and discharging upon either of the second pair of main bands by way of a two-way distributor. The cross travelling bands are each driven by a 15 B.H.P. enclosed motor mounted on the carriage. The four conveyor bands are continued through the second tunnel section to the junction with the third section, where the tunnel makes a square turn and runs from the dock wall to the basement of the granary. The conveyors in the third section are about 320 ft. between terminals, and to equalise the drive some 200 ft. length of bands in the second section are driven at the angle by means of cut bevel gearing and roller chain drives. Thus each length of band per motor is approximately equal, and similar 30 B.H.P. motors are adopted for each conveyor. The conveyors in the third section are provided with travelling throw-off carriages for use near the extreme end where the tunnel opens out into a spacious chamber near the granary basement. Here the grain is weighed by automatic weighing machines and discharged into the boots of the four main elevators, each capable of lifting 100 tons per hour to the top floor of the granary. The main elevators deliver the grain to the four bands traversing the whole length of the granary over the heads of the silos and grain floors, and by means of travelling throw-off carriages provided on each of the bands the grain is discharged into any one of the seventy-eight silos or upon any of the grain floors. The four weighing elevators and four main elevators are driven each by a 30 B.H.P. motor, each motor at the same time driving a length of conveyor band. The grain floors are fitted with 12-in. diameter steel shoots, continuous through all the floors down to the sacking-off platform, valves being fitted for receiving and discharging the grain at any floor. An interesting feature in connection with this machinery is the arrangement of "re-elevating" bands in two small subways constructed under the granary. By means of these conveyors grain can be taken from any silo or any part of the floor granary, reweighed and re-elevated to another silo, or placed upon any other floor as may be desired, or heated grain can be circulated from silo to floor or vice versa, and small parcels of grain can be removed from the silo to a floor to make room for incoming grain. Each of these bands is driven by a 15 B.H.P. enclosed type motor. For the dispatch of grain to coasting steamers or to other small craft a special conveyor for carrying loaded sacks or loose grain has been erected in an overhead gallery. The inner end of this conveyor extends below the sacking-off platform. The sacks or loose grain are passed through openings in the platform on to the band, and are delivered at the dock side through shoots into various craft. This conveyor is fitted with two-speed gear, the band speed for loose grain being 650 ft. per minute, and that for sacks 200 ft. per minute. The band is in two sections of unequal

length. The inner section of 450 ft. is driven by a 30 B.H.P. motor and the outer length of about 220 ft. by a 15 B.H.P. motor placed in a house below.

All the elevators and conveyors are driven from their respective motors by cut gearing and roller chains.

Immingham Dock Granary.—The general arrangement will be seen from the illustrations, Figs. 1084 and 1085. Figs. 1086 and 1087 give two cross sections; whilst the granary itself is represented in plan by Fig. 1088; the top floor in Fig. 1089.

The dimensions of the building are about 127 ft. by 137 ft. 6 in. Of the latter dimension 74 ft. are occupied by the silos, whilst the remaining 63 ft. 6 in. constitute the floor granary, which extends to six floors above the ground floor.

The silo portion of the granary consists of 82 silos, each 10 ft. square in the clear, and the height from the hoppers to the floor above the bins is approximately 50 ft. The walls of the silos are 6 in. thick, reinforced with horizontal and vertical rods in both faces. The bins are designed to act independently, that is to say, one bin may be full of grain and the adjoining bins empty without causing undue stress to the structure. All internal angles are finished with a 3-in. splay, and $\frac{5}{8}$ -in. rods are provided at 12-in. intervals across the corners to form ladders for access to the bins. The bottoms of the bins are splayed to the outlet and have reinforced concrete varying from 4 in. to 5½ in. in thickness, with beams formed in the angles under the walls, practically of triangular form, with a width of 3 ft. at the bottom. The bars from the walls and the sloping bottoms are carried well into these beams, which are in turn connected to the columns which serve to support the bins. The silo bottoms are of cast iron.

The external walls of the silo portion of the building are formed of 8 in. of concrete in the lower 25 ft. and 6 in. above this level, with piers 3 ft. wide at 10-ft. centres projecting 5 in. on the outside of the building and having a flush face on the inside. The string-course and cornice, which are of reinforced concrete and hollow in the interior, were cast on a form of collapsible centre in convenient lengths and built in position as the walls were carried up. The floor over the silos is formed of 4 in. of concrete, reinforced with $\frac{3}{8}$ -in. rods in both directions and finished with granolithic. The size and details of the columns vary, those attached to the walls as piers being generally 3 ft. wide and projecting 8 in. or 10 in. from the face of the wall, whilst the reinforcement consists of eight lines of vertical reinforcement, well tied with links at about 8 in. pitch. Those under the bins vary from 21½ in. square to 22½ in. square, reinforced with eight bars varying from 1½ in. to 1⅝ in. diameter, four of these being placed at the corners of the columns, whilst the remainder are placed in the interior to form a square core with a 5½-in. side. The outer rods are tied with $\frac{3}{8}$ -in. links at 8-in. centres, while the inner rods have no binding on account of the large amount of concrete around them.

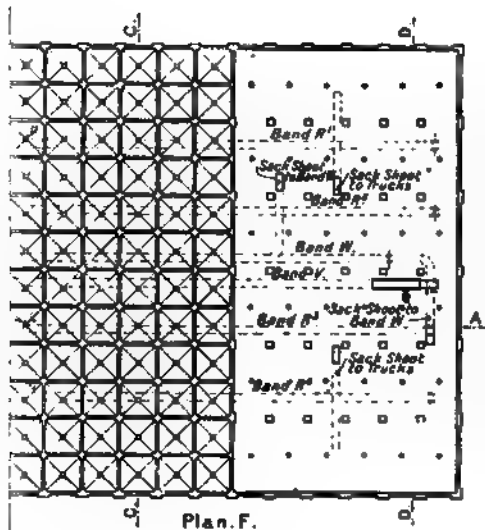
The floors of the granary portion of the building, which adjoins the silos on the opposite side to the receiving house, are designed to carry a safe loading of 3 cwt. per foot super., are 5 in. in thickness, carried on secondary beams having a span of 10 ft. 6 in., which in turn are carried by main beams spanning about 20 ft. The slabs were made 5 in. thick and are reinforced with ¼-in. bars at 4½-in. centres across the span of 7 ft., these bars being continuous over three bays, and similar bars at 12-in. centres are placed at right angles to these. The secondary beams are 8 in. deep and 6 in. wide, reinforced with 1½-in. twin rod and hangers and bonders about 12 in. apart, while the main beams are 18 in. deep and 7 in. wide, reinforced with a 1½-in. twin rod, with provision for shearing stress. The interior columns are 26 in. square and have fourteen vertical bars, ten placed near the outer surfaces, having a diameter of 1⅝ in., and the remaining four are

SECTION A A

Fig. 1086. Longitudinal Elevation.

Section B B

Fig. 1087. Cross Section.



Plan through Silos and Floor Granary.

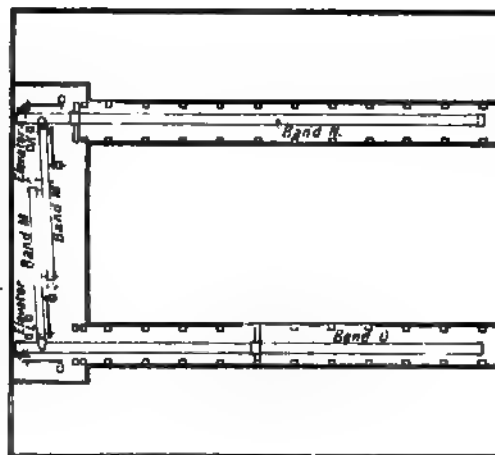


Fig. 1089. Plan of Top Floor.

placed within the core and have a diameter of 2 in., the whole being bound by $\frac{3}{8}$ in. links at 8-in. centres. The external walls are 6 in. thick in the panels, whilst floor beams which come against the exterior are carried by projecting piers 3 ft. wide.

The towers at the receiving house end are carried 32 ft. above the cornice of the main buildings, and these are formed with 6-in. walls strongly reinforced, and have a reinforced concrete string-course and cornice of similar construction to that previously described. The receiving house at the back of the silos is 43 ft. by 27 ft. 6 in. by 67 ft. high, and has three floors.

The concrete throughout was mixed in the proportions of 9 cub. ft. of aggregate, $4\frac{1}{2}$ cub. ft. of sand, and 224 lb. of cement. All the floors are finished with granolithic paving composed of five parts of granite to two parts of cement. The concrete foundations were carried on wooden piles driven in groups proportionate in numbers to the loads to be carried, as many as eight being placed together in some instances. The piles varied from 45 ft. to 50 ft. in length, and the soil in which they were driven was a thick mud.

Quite apart from its constructional features, this grain storage installation is of more than ordinary interest, by reason of its machinery equipment and the efficient conveying plant which has been introduced. The store is capable of holding 20,000 tons of grain, partly in silos and partly on open floors. As will be gathered from the illustrations, two overhead gantries, which are fitted with band conveyors, form the means of communication between the receiving shed of the granary and the ship elevator. The latter, which is of the travelling type, runs on rails and forms a complete machine in itself, having bands, elevators, weigher, and motors. It is so constructed as not to interfere with the free passage of railway trucks along the dock side, being raised on legs, which is a novel feature. The leg of the elevator can not only be raised and lowered, but it can also be swung from side to side, thus enabling a large area to be covered without it being necessary to change the position of the boat which is in course of unloading. The ship elevator, when not in use, can be raised out of the way, and this raising and lowering is effected by means of an electrically driven winch in the tower, and the elevator is balanced by weights, which greatly facilitates the operation. The elevator is capable of dealing with 150 tons of grain per hour. Vessels in any position on the quay side can be dealt with, and the following sequence of operations briefly explains the method of unloading.

The ship elevator is lowered into the hold, and the grain elevated, weighed, and passed on to 27-in. wide band conveyors in the gantry parallel to the wharf, which feed on to either of the two bands, one 27 in. and the other 36 in., in the other gantry. The grain is then elevated by one of two 150-ton per hour elevators to the top of the silo building, and from thence it is distributed to any required bin or storage room.

The front gantry, alongside which the ship elevator travels, is 530 ft. long, and grain is taken in from the ship elevator at any point along this distance. The approach gantry leading to the receiving house is 300 ft. long. There are eighty-two bins and six storage floors, and these latter are each arranged with thirty-six floor spouts, which are fitted with sliding sleeves at the top and bottom, by means of which the grain may be fed to or taken from any floor. By raising the top sleeve and placing a conical cap or spreader on to the spout, the grain may be distributed over the floor to any required height. To discharge the grain it is necessary to raise the bottom sleeve and to lower the same when sufficient grain has been drawn off. For taking out sacks from the granary, they are carried on the bands in the approach gantry to an outside conveyor in the centre of the front gantry, delivering direct to ships and barges. This conveyor may be housed in a

tower in the centre of the front gantry. The band is completely enclosed, and there is thus no risk of the grain being damaged when being loaded out. This band may also be used for loading out in bulk.

On the first floor of the building are six Avery portable grain weighers with sacking-off appliances. The grain, when sacked off, can be delivered by sack shoots either into trucks or on to sack bands, which extend along both gantries and thence through shoots into boats. The outgoing grain can also be handled in bulk with equal facility. On the ground floor a number of conveyors are placed, and these are fed from the silos, and delivery of the grain is effected to either of the elevators. These conveyors are used for turning over purposes. The bands, over the silos and floor storage, are capable of dealing with 300 tons of grain per hour.

The machinery equipment includes twenty-two motors with an aggregate of 270 H.P. The majority of the motors are back-geared, and the band conveyors and elevators are driven by chains, thus obviating the use of the large gear wheels generally found on elevator heads. This method of drive is stated to have proved very satisfactory, light, and remarkably free from noise. The power is transmitted to the travelling ship elevator through a series of plugs placed along the front gantry, a loud speaking telephone being meanwhile connected up by the single plug.

The buildings were constructed by Stuart's Granolithic Co., Ltd., of Bedford Row, W.C., and the gantries and grain-handling machinery were manufactured and erected by Henry Simon, Ltd., of Mount Street, Manchester—all to the requirements of Mr J. B. Ball, M.Inst.C.E., the engineer-in-chief of the Great Central Railway Co.

No. 2 Manchester Dock Granary.—This granary is situated at the head of the large No. 9 Dock, Manchester, and is owned by the Manchester Ship Canal Company. It has a holding capacity of 40,000 tons or one-and-a-half million bushels of grain. The complete installation was designed, and the contract for the building of the granary, together with the whole of the machinery equipment, was carried out by Henry Simon, Ltd., Manchester.

Unlike the first granary of the Manchester Ship Canal, the building of the second (see Fig. 1090) is composed of reinforced concrete, comprising 260 storage bins and 81 shipping bins as well as distributing, weighing, and loading out floors. The building is of rhombus shape, 295 ft. long and 165 ft. wide, and the total height from the quay level to the top of the hoist tower is 168 ft. Plan, longitudinal and cross section of this granary are shown in drawings, Figs. 1091, 1092, and 1093.

The foundations consist of 206 piers, 149 of which are interior piers, the remainder being placed along the sides and ends of the building. They are spaced 14 ft. centres lengthwise of the building, and 11 ft. 8 in. centres across the building, and extend a distance of 13 ft. below the basement floor. Mass concrete was used in these. These piers are connected together at the base in a lengthwise direction by concrete blocks 2 ft. thick, reinforced by rows of 1-in. diameter steel rods spaced 5 in. apart, and in a crosswise direction by concrete blocks of the same thickness, but with rows of 1-in. diameter rods spaced 1 ft. apart. The rods in both directions project 2 ft. into the column base at each end. These foundations were put in at the time the No. 9 Dock was built, and the contract for the new granary was for the design and construction of all work above this point.

The floor of the basement is $5\frac{1}{2}$ in. thick and of mass concrete, without any reinforcement, and a fall of 3 in. has been allowed to a drain on one side of the building. The columns commencing on the piers of the basement floor level, together with the whole of the building above the quay level, are of reinforced concrete. The interior columns

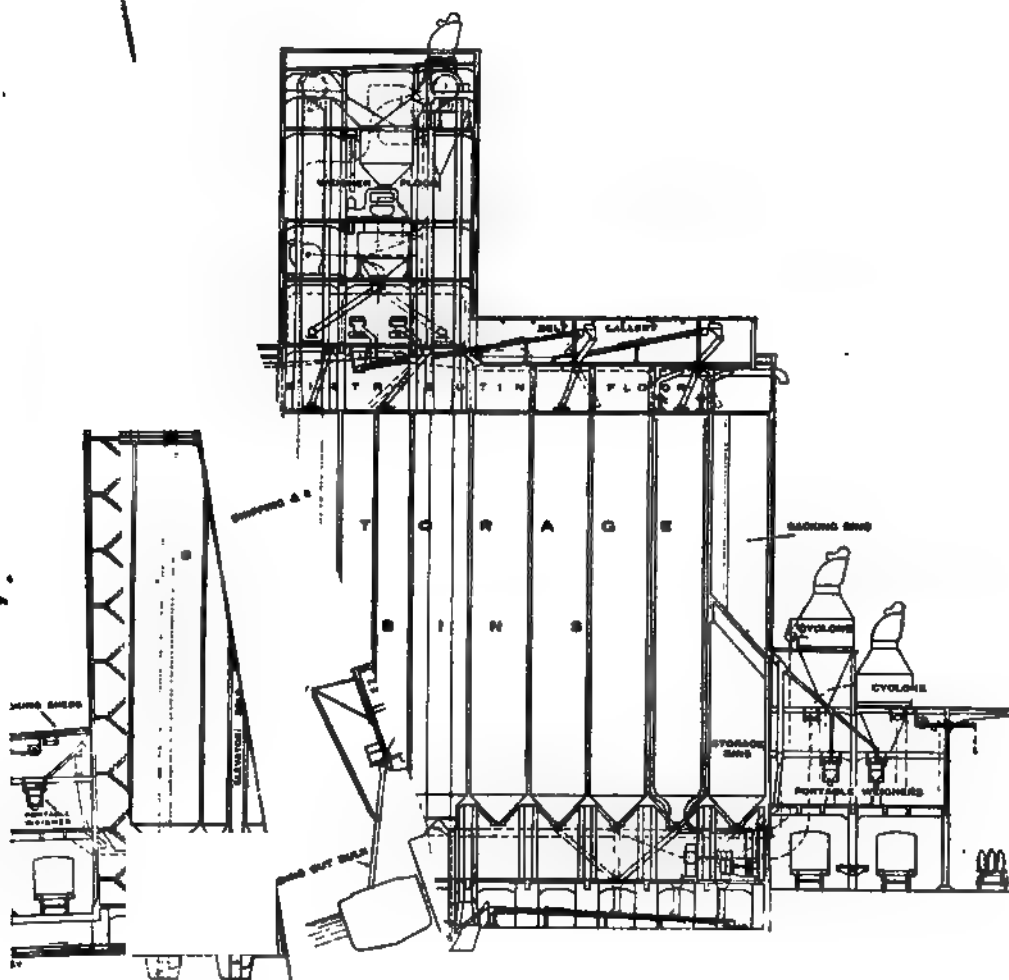


Fig. 1092

Cross Section.

(To face page 740.

from the basement to the ground floor level are octagonal in shape and are 58 in. width across the flats at the base, tapering in a height of 55 ft. to 42 in., while those between



Fig. 1090. Rear View of No. 2 Manchester Dock Granary.

the ground floor and the level of the bin hoppers are similar in shape but are 42 in. across the flats. The estimated weights carried by each of these columns range from 335 to 620 tons, and the reinforcement varies in accordance with the load. The external columns of the building rise from the piers at quay level, and carry loads

varying from 265 to 380 tons. The walls to the level of the hoppers are 4 in. thick, and are built between the columns to form panels in which windows are provided.

The ground floor, which is 9 ft. 6 in. above the basement, is of beam and slab construction, the main beams being 20 by 10 in. in section, and the subsidiary beams 17 in. by 6 in. The floor is $5\frac{1}{2}$ in. in thickness with finished surface, and reinforced with $\frac{3}{16}$ -in. diameter tension and compression bars laid in both directions and bound together at the intersections to form a continuous mat.

The columns on the ground floor are connected together at the top in both directions by reinforced continuous concrete beams of triangular section from which the bin hoppers are carried. These hoppers are entirely self-discharging, the inside corners being banked up with concrete at an angle sufficient to allow this. Each hopper is provided with a 12-in. square outlet, a cast-iron lining being built in to carry the bolts supporting the slide valves as well as to protect the edges of the concrete from the wear of the grain. The section of the building between the crown of the hoppers and the first floor is divided into 274 separate compartments, 260 of which are bins, and the remainder, twelve elevator belt ways, one stairway, and one combined stairway and hoist well. The whole of the 260 bins have hopped outlets on the ground floor, but the upper portion of 47 of the bins, along the sides and ends of the building, are subdivided by vertical walls into 81 extra bins with hopped bottoms sloping to the outer walls in which openings are provided for discharging grain to the delivery sheds round the building. These bins are for sacking-off and delivery purposes, and the 260 bins with outlets on the ground floor are for the storage of the grain. These vary in section from 14 ft. \times 11 ft. 8 in. to 6 ft. 6 in. \times 6 ft. 6 in., with a depth of 75 ft. above the crown of the hopper. The sacking-off bins have a depth varying from 48 ft. to 58 ft., and the total holding capacity of the 341 bins is about 40,000 tons of wheat. In order to economise storing space, the continuation of the column on the ground floor is continued in the bin corners in such a way as to occupy the least possible space. The walls are of the same thickness throughout the whole depth, but vary in the different sized bins from 6 in. to 9 in. The floor over the large bins is of beam and slab construction, whilst that over the smaller ones is of slab construction only.

Provision for feeding grain to the bins is made by building into the floor over each bin a circular cast-iron frame with a removable lid, and manholes are also provided in the same manner. The storage bins under the shipping bins are filled and emptied via a concrete passage located in the corner of the shipping bins.

Above the bins is the cupola or working house (see Fig. 1094), and being smaller in area than the bin floor, it is arranged directly over the section containing the elevators, which are on the side of the granary facing the dock. This cupola is rectangular in shape, 238 ft. long and 37 ft. wide, and rises to a height of 70 ft. above the bin floor. It consists of four floors, designated the second, third, fourth, and fifth, whilst, at a slightly lower level than the second floor, six galleries extend out over the portion of the bin floor not covered by the cupola. Four of the galleries extend to the outer wall of the building, the ends being arranged for the reception of bridges to connect up to a future extension of the granary.

Owing to the fact that the cargoes received at the port of Manchester often comprise part grain and part general merchandise, arrangements have been made at No. 9 Dock for unloading general goods and grain in sacks at the same time as grain in bulk to the granary, or overside to barges. Bulk grain for the granary is delivered through spouts to band conveyors running in subways underneath the north and south quays of the dock itself. These are shown on the isometric diagram, Fig. 1094. The north subway

Fig. 100A. Isometric Diagram of Bulk Grain-handling System at the No. 2 Manchester Dock Granary.

Fig. 1442. Isometric Diagram of Sacking on and Loading-out Arrangement of the No. 2 Manchester Dock Granary.

extends about 950 ft. along the dock, and at the quay is room for two berths at which full cargoes of grain are unloaded. The south subway extends the full length of five berths, and is about half a mile long, and at this side of the dock grain can be taken from ships at the same time as general merchandise is being discharged. The conveyors in these subways can be fed from numerous points along the quay, so that it is not necessary to move a ship after unloading has commenced.

By the arrangement of the subways and conveyors, it is possible to have three streams of grain running in each subway at the same time, which gives a total of six separate streams, and as each conveyor can deal with 200 tons of grain per hour, it will be clear that the plant has an intake capacity of 1,200 tons per hour.

Fig. 1006. One of the Band Conveyors on the Distributing Floor above the Bins of the No. 2 Manchester Dock Granary.

The subway conveyors feed to cross conveyors in the passages and basement of the granary which in turn feed to six receiving elevators (see Fig. 1004). These carry the grain to the top of the granary and deliver to 2-ton "Avery" automatic weighing machines, each of which delivers its load to a 60-bushel hopper fixed on the third floor of the cupola. These hoppers are of steel and are fitted with rotary outlet valves. A swivelling spout supported upon a radial arm is fitted to each rotary valve, so that grain can be fed either to the distributing conveyors on the second floor, or direct to revolving telescopic spouts. These swivelling spouts are also arranged to feed direct through stationary spouts to a conveyor on the floor above the bins, which in turn feeds the sacking and shipping bins on the west side.

Along the west or dock side of the sacking shed eight spouts are built into the

outer walls, to which swivelling telescopic spouts are connected for loading bulk grain to barges, or in bulk to railway wagons and carts. Isometric diagram, Fig. 1095, shows the arrangement of the loading out into railway trucks and barges. One of the band conveyors, on the distributing floor above the bins, is shown in Fig. 1096. A "Simon" separator, with a capacity of 4,000 bushels per hour, is provided for cleaning purposes, and four bins are also set aside for cooling heated grain.

The whole of the motors in the building are of the totally enclosed type, and are pipe ventilated. The motors driving the cooling fans and lifts are self-ventilated, being connected to the outside atmosphere by sheet steel pipes. The remainder of the motors have air blown through them.

A very complete dust collecting system is provided. The garners above the weighers are each fitted with an inlet pipe through which air is drawn, and sweep-ups are provided on all floors. The separator and elevator heads and boots are also exhausted, and the dust collected in cyclone dust collectors.

The granary equipment also includes electric goods and passenger lifts by means of which communication is established between all floors. The granary is electrically lighted throughout.

Meadowside Dock Granary, Glasgow Docks.—This granary was built by the Trustees of the Clyde Navigation, according to the design and specification of their engineer-in-chief, Mr W. H. Alston. The contract for the building was carried out by John Train & Taylor, Rutherglen, Glasgow, whilst that for the mechanical equipment was executed by Spencer & Co., Ltd., Melksham, on the most modern and up-to-date lines, their extensive experience in this class of work being well known. The granary is erected at the Meadowside Wharf, practically parallel to, but at about 220 ft. from the quay on the riverside, at the port of Glasgow, some $2\frac{1}{2}$ miles from the centre of the city (see key plan, Fig. 1097, and photographic view, Fig. 1098).

At the wharf there is berthage for three of the largest grain-carrying ships, and for the unloading of these there are two travelling ship-discharging elevators, each capable of raising grain from the holds at the rate of 250 tons per hour. They discharge the grain, after weighing it, on to either of two conveyor bands, working in a subway built parallel with the face of the quay. Since the grain cargoes arriving at Glasgow are not separated by mats into small parcels, bucket elevators have been installed in preference to pneumatic elevators, because the former are more economical in power consumption.

The Building.—Two methods of construction were adopted in the granary building; the outside walls of the floor granary are built of brickwork, and the internal structure is formed of cast-iron columns, rolled steel joists, and concrete floors. The construction of the silos, with their partitions, is of ferro-concrete, while, for the sake of uniformity, the outside walls of this part also have a facing of brickwork.

The installation is illustrated in the four plans (Figs. 1099, 1100, 1101, and 1102), longitudinal section (Fig. 1103), and three cross sections (Figs. 1104, 1105, and 1106). A plan of the basement subway under the loading floor is shown in Fig. 1099, together with a portion of the intake subway. In Fig. 1100 is shown a plan through the silos and storage floors, the silo portion of the granary being on the left and the floor granary on the right. A plan of the ground floor, or loading platform, is given in Fig. 1101, showing the shoots from the silos and storage floors for feeding the bands for redistribution of the grain, for delivery in sacks to carts, railway trucks, or in bulk and in sacks to river craft. A plan of the conveyor gallery and part of the twelfth floor is shown in Fig. 1102. A longitudinal section of the building from east to west is shown in Fig. 1103. Fig. 1104 is a cross section through the silo granary looking west; while Fig. 1105 is a cross section

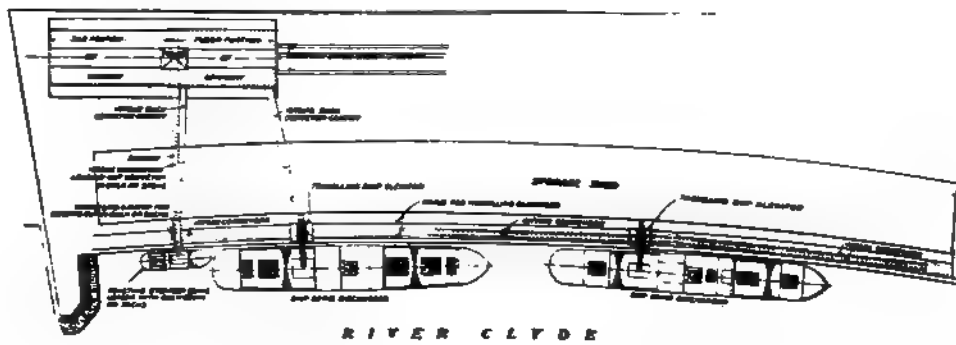


Fig. 1097. Key Plan of Meadowside Dock Granary, Glasgow.

Fig. 1098. General View of Meadowside Granary and Ship-Discharging Elevators for Clyde Navigation, Glasgow.

through the centre of the granary looking west, showing part of the basement and loading floor, and also a section through the tower (36 ft. by 24 ft.) which projects beyond the roof and rises to 160 ft. above the ground. A cross section through the floor storage granary is represented in Fig. 1106.

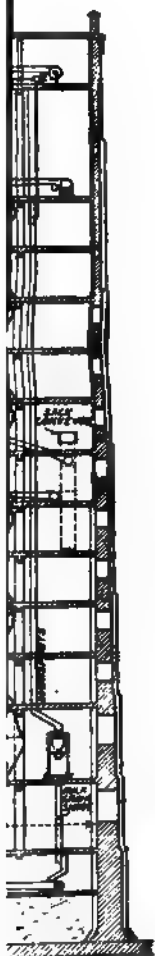
The total length of the building, inside, is 312 ft., the width 72 ft., and it has a total storage capacity of 31,000 tons of grain. The part occupied by silos is 168 ft. long, and there are 150 separate bins, of which 38 are 102 ft., and the others 84 ft. in depth; the aggregate capacity of all the silos is 20,000 tons. That portion of the building divided up into floors is 144 ft. in length, the height from floor to floor is 8 ft. 6 in., and the eleven storage floors are so arranged that grain can be stored to a depth of 5 ft. 6 in. on each: the total amount which can thus be accommodated is 11,000 tons. A sacking-off floor, 12 ft. 6 in. in height, runs the whole length of the building at a height of 15 ft. 6 in. above ground level, to permit of railway wagons passing beneath on three lines of way, alongside which there are three loading platforms (see the three cross sections, Figs. 1104, 1105, and 1106).

Ship-Discharging, Inward Conveying, and Distributing Machinery.—On the river side of the granary are two ship-unloading elevators, mentioned in the beginning of this description (see Figs. 1107 and 1108), which travel on a rail-track of 20 ft. gauge and 900 ft. long. Each elevator is capable of handling 250 tons of grain per hour from a steamer and depositing it on to one of two band conveyors located in a subway which runs parallel with, and in reach of, the elevators. Two automatic weighing machines, with a capacity of 4,000 lb., form an integral part of each of these elevators. The grain is thus weighed before being passed on to the band conveyors. From these two band conveyors the grain is passed on to two transverse band conveyors, also in an underground passage connecting quay and granary, which ultimately carry it to the bottom of the main elevators in the centre of the granary. The two main intake elevators are marked C1 and C2 on Fig. 1099: the two conveyors over the silo portion of the granary are marked D1 and D2 (Fig. 1102), while the two over the floor granary are marked D3 and D4. The grain is raised to the conveyor gallery at the top of the building by the two main elevators, and discharged for distribution on to troughed band conveyors running east and west. Conveyors D1 and D2, extending over the silo portion of the granary, can deposit grain into any one of the 150 separate bins. The other two conveyors, D3 and D4, can deposit grain on any of the eleven storage floors by means of vertical down-spouts, spaced 12 ft. apart, all over the floor granary.

The two ship elevators travel electrically along the quay at a speed of 20 ft. per minute; the approximate weight of each of these is 200 tons. The extreme working positions are shown in dotted lines in the illustration (Fig. 1107), and this range covers both the largest and smallest vessels at all states of the tide. The telescopic shoot is shown delivering the grain into the hoppers at the lower terminals of the two weighing elevators. The maximum intake can be dealt with expeditiously by means of the two weighing elevators mentioned above, which are placed in the sides of the structure, each delivering into an automatic weighing machine, without retarding in any way the continuous flow of grain.

After being weighed, the grain is discharged through the fixed shoots in the quay on to either of the two conveyors in the subway, as mentioned. These conveyors are in duplicate, and each is capable of dealing with 250 tons of grain per hour, so that both ship elevators can work at the same time. The quay is on a curve of one mile radius, and the conveyors are arranged in a series of tangential straights, feeding on to each other.





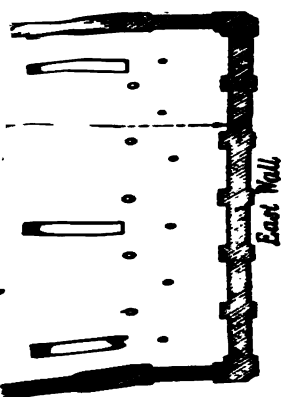
Elevator

Fig. 1106. Cross Section through Floor Granary,
looking West.

[To face page 148.]



as of 1



of Meadows side II



Facilities for Turning Over Grain.—It may be desired to condition grain, by turning it over, after it has been stored in the silos, for which purpose there are three lines of conveyors in the basement, capable of dealing with 100 tons per hour each, extending from the ends of the building and delivering to either of the three elevators, C1, C2, and C3. Grain can be dealt with in this way from any silo bin or floor of the granary. By means of portable shoots under the bins, or in continuation of the downspouts, as the case may be, the grain is delivered on to one of the basement conveyors, F1 to F6, already referred to, and shown in Fig. 1099. The centre conveyors, F2 and F5, deliver direct into the boots of the main elevators at the centre of the building; grain carried by the side conveyors (F1, F3, F4, and F6) is brought to the same point by means of short transverse bands at the north end of the intake subway, or by the inner length of the main intake bands from the quay, as the case may be. By the main elevators the grain is raised in the conveyor gallery, and is distributed to bin or storage floor, as in the case of grain entering the granary ex ship. The basement conveyors can also be arranged to deliver to an auxiliary elevator, C3, discharging into an automatic weigher placed on the ninth floor. This machine has a capacity of 3,000 lb. per weigh, and can be used for recording the weight of parcels of grain that are being turned over in the granary, or for weighing larger parcels of grain being discharged direct to railway truck or direct to craft through the leading-out band in the intake subway, to be described later.

The auxiliary elevator, C3, is carried up to the same height as the main elevators, and is thus available for turning the grain over either from the silo or granary, in the event of the main elevators, C1 and C2, being engaged in taking in grain from the ship elevators, provided that one of the appropriate bands in the conveyor gallery is not in use in connection with the main elevators.

We have now followed the grain from the vessel to the two main elevators, C1 and C2, in the central tower of the granary, and thence to the distributing conveyors, D1 to D4, in the gallery, and eventually to their respective storing places.

Warehousing Grain and Flour in Sacks.—Arrangements for conveying grain and flour in sacks from the quay to the granary will next be considered. At the east and west ends of the floor granary, two inclined band conveyors are provided, each capable of dealing with 500 sacks per hour. These take the sacks into the granary. They start from ground level near the front of the quayside shed, pass through the roof of the shed, and are carried by two steel trunks across the intervening space and enter the granary at the sixth floor (see Fig. 1106). The driving motors and band-tightening gears are on the fifth floor, and the terminals on the sixth floor. The bottom ends of these conveyors, in the goods sheds, are hinged, so that they can be hoisted out of the way of the traffic when not in use.

A reversible sack band, running east and west inside the granary, distributes the sacks on the sixth floor, and by nine patent "Swiftsure" sack shoots to any of the lower floors, or else to railway wagons, carts, or finally to the six basement bands for loading out to craft at the quay. The eastern sack intake band is continued by an inclined band along the east end and north side of the building, by means of which the sacks can be taken to the twelfth floor and delivered on to a distributing band there, similar to that on the sixth floor. This inclined band inside the granary is enclosed by partition walls and sloping ceilings, and alongside the band there is a walking space, with short stairs at intervals giving access to the successive floors.

The "Swiftsure" sack shoots, mentioned above, are on continuous vertical lines, extending from the twelfth floor to the basement bands. A descending sack has first



Fig. 1107. One of the Travelling Elevators on the Quay for Discharging Grain from Ships.

a vertical drop for about half the height between floors, and then slides on to a nearly horizontal portion of the shoot, the change in direction being effected by a properly designed curve. If the sack is at an intermediate stage of its journey, it retains sufficient velocity to carry it forward to the next vertical drop pertaining to the floor below, followed again by the horizontal portion of the shoot. The complete movement of the sack through a number of floors is therefore on a zigzag path. On the floor at which it is desired to intercept the sack, the side of the shoot is opened, and by the movement of a lever, a baffle-plate comes into action and brings the sack to rest on the horizontal portion of the shoot, from which it can be removed by hand.

Machinery for Outward Loading of Grain in Bulk or in Sacks.

—Grain brought from any floor by vertical down-spouts or drawn from bins, is weighed on the first floor, for which purpose 14 automatic weighing scales are provided; it is then sacked if required, and discharged by gravity, in sacks or in bulk, into carts outside the granary, or into railway wagons on the three lines of rails inside. Provision is made for loading, simultaneously, 24 carts or lorries, 12 along each side of the granary. Loading takes place under cover of an overhanging verandah roof, projecting 16 ft. from the face of the main building. Ten railway wagons on each line of rails, or 30 in all, can be loaded simultaneously.

In order to facilitate loading grain out into lighters a band conveyor, designated *c* in Figs. 1099 and 1105, and capable of carrying 100 tons of grain in bulk or 500 sacks per hour, is provided in the intake subway at



Fig. 1108. Section through one of the Elevators on the Quay shown in Fig. 1107.

a higher level than the main intake bands. Under the goods shed on the quay this band is run on an upward incline, in order to deliver to a continuous band carried on a travelling gantry which runs on the same rail-track on the quay as the ship elevators, and from which the grain, in sacks or in bulk, is delivered to the steamer or lighter. The top portion of this gantry, which is fully illustrated in Figs. 1109, 1110, 1111, is at a sufficient height to clear railway wagons running on possible future lines on the quay. The inclined portion of the band inside the shed is carried on a lattice framework, hinged on the front eaves girder of the shed, and provided with lifting tackle at the inner end, by which it can be raised up towards the roof of the shed when not in use.

The loading-out band is fed at its inner end by any of the longitudinal basement bands in the granary, on to which the grain has been discharged by shoots, as already described, for the turning-over process and loading into railway wagons. Instead of being weighed by the portable machines on the first floor, the grain, if in a large parcel, may be weighed by passing through the automatic weigher on the ninth floor, above referred to, and the relative shooting discharging on to the centre basement band F5. From the travelling gantry in front of the goods shed the grain, whether in bulk or in sacks, is discharged by fixed and portable shoots into the craft lying alongside the quay.

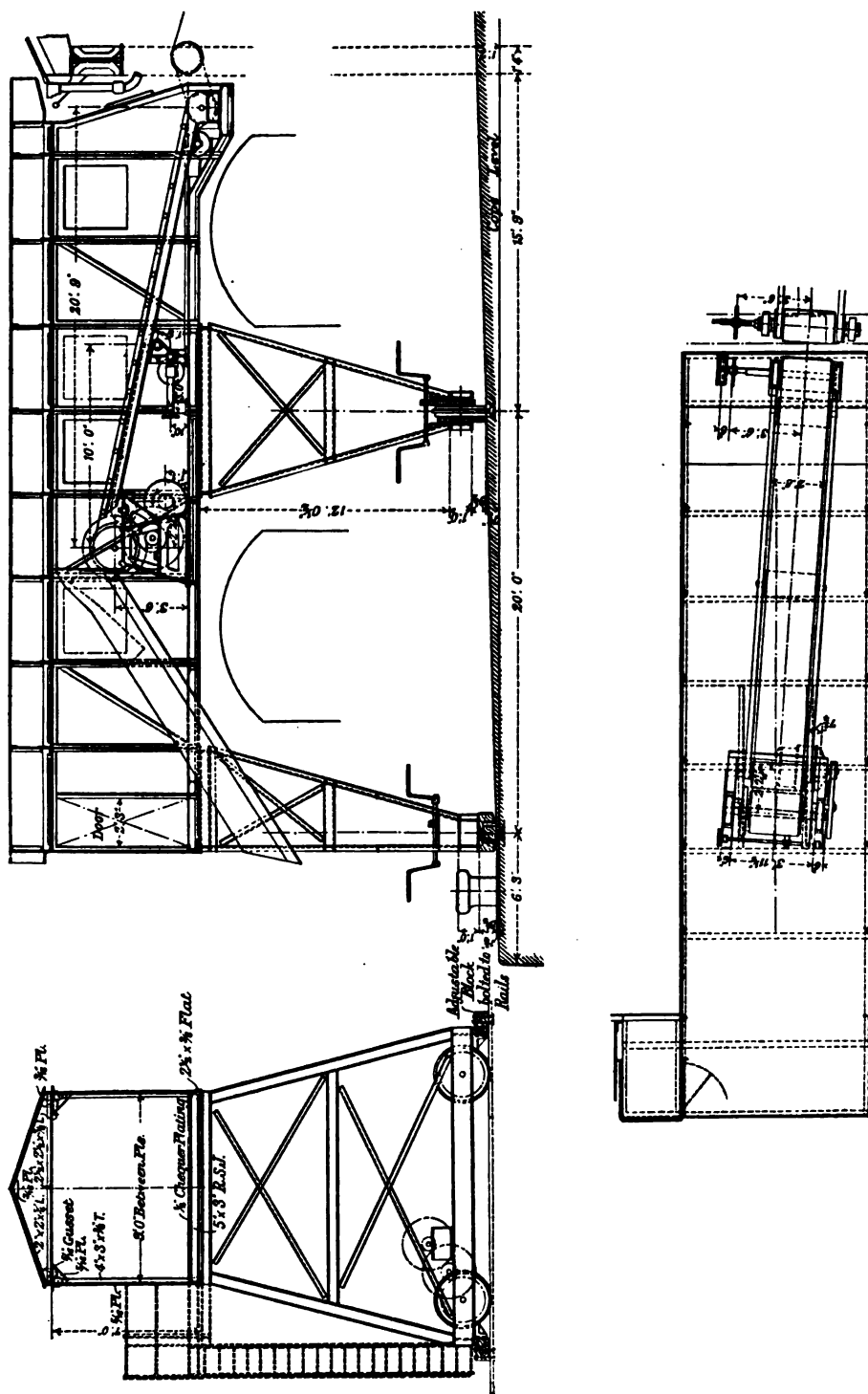
The system of sack shoots and bulk shoots to wagons is shown in Figs. 1103, 1104, 1105, and 1106. The railway lines pass through the building, and by means of an electric traverser, placed in a pit at the west end, loaded wagons can be transferred to other lines between the granary and the goods shed.

Ventilation.—The granary is equipped with two separate dust extracting plants—one for ventilating the quayside and intake subways, the other, the subways in the basement. The fans are direct-driven by motors, and are of ample size to deal with all dust arising from the grain at the feeding-on and delivery points on the conveyors, so that the subways are kept perfectly clear. The dust is discharged from the fans through the north wall of the building into two large cyclone dust collectors, from which it is led by spouts to the loading platform, where it is sacked.

Electrical Fittings.—The whole of the grain-handling machinery is driven by electricity, direct current at a voltage of 500 being supplied by the Glasgow Corporation Electricity Supply System.

There are thirty-nine motors, all of which are totally enclosed, the aggregate horse power being 678. All motor-starting panels, except those in the quay subway, are of the ironclad type, consisting of a rheostat (with no volt and overload release) operated by means of a handle from the outside of the casing, and a double-pole magnetic circuit breaker, which is closed by the starting switch. The motors driving the quay subway conveyors have automatic control panels, consisting of an enamelled slate base fitted with a solenoid operated starting rheostat, double-pole throw-off switch, single-pole magnetic circuit breaker, double-pole single-throwover main switch, and a no volt and overload release. These panels are designed for remote control, being operated by master switches, four in number, fixed on columns of the goods shed facing the river. These eight panels are all electrically interlocked, making it impossible to start up the two bands at the far end of the subway—*i.e.*, B1 and B2—without all the preceding bands starting up simultaneously. In like manner, should the bands nearest to the intake elevators—*i.e.*, B7 and B8—be stopped for any reason, then all the other bands beyond will also stop, and if bands B5 and B6 be stopped, then B3, B4, B2, and B1 will also stop, but B7 and B8 may be kept running. Also, should bands B3 and B4 be stopped, then B1 and B2 will stop with them, and bands B5, B6, B7, and B8 may be kept running. Thus all fear of a choke of grain in the subway is reduced to a minimum. The remote control may, if necessary, be cut out and the panels operated locally by means of the double-pole throwover switch mentioned above.

The ship elevators are electrically connected by flexible cables, protected in a metallic flexible tube, fitted with a plug to connect up to plug boxes, twenty-one of which are built into the surface of the quay, these plug boxes being fed from the mains in the quay subway. A driver's cabin is provided, where all the control gears for the different motors are grouped together conveniently for the operator. Trimmer-winchies are included for bringing the grain in the ship's hold up to the elevator boots, and are



Figs. 1109, 1110, 1111. Plan and Two Elevations of Travelling Gantry for Shipping Grain in Bulk or Sacks at the West End of the Quay.

provided with magnetic clutches, which are operated by means of push buttons fixed at the bottom of the elevator legs.

There is a complete telephone system installed, there being one instrument on each floor, and one at each master switch along the quay; all are connected through a central exchange. The ship elevators are provided with an electric bell signalling apparatus from the driver's cabin to the quay level, so that the driver may be warned in case of emergency.

The writer is indebted to Spencer & Co., Ltd., of Melksham, and to the editor of *Engineering* for the information and illustrations.

The Largest American Granaries.—The largest granary in the United States, from the standpoint of storage capacity, is the North-Western Railway Granary in South Chicago, with a total capacity of 10,000,000 bushels; 46 band conveyors and 45 belt elevators are used. The same, or similar, compound cotton-rubber belts are used as well for supporting the elevator buckets as for the band conveyors. The total length of belts employed is 39,149 ft.; they vary in width from 14 in. to 42 in., and in thickness from 4 to 7 ply.

From the standpoint of handling capacity, the new Pennsylvanian Railroad Granary at Baltimore is the largest. There are employed in this installation 69 conveyors and 19 bucket elevators. The storage capacity is 5,080,000 bushels, and the loading capacity is 1,800,000 bushels per day.

SOME OF THE PRINCIPAL GRANARIES IN GREAT BRITAIN.

Name of Owner and Title of Granary.	Material Used and Nature of Granary.	Capacity. Qrs.
Atlantic Wharf Grain Silos, Cardiff	Ferro-concrete silo granary	33,000
Bristol Dock Co.—		
Avonmouth Dock Granary	Floor granaries	50,000
Portishead Dock Granary	„ „	60,000
Princes Wharf Dock Granary	„ „	70,000
Clyde Navigation—		
Meadowside Granary, Glasgow	Floor and silo granaries of ferro-concrete	144,666
Co-operative Wholesale Society, Ltd.—		
Granary, Dunston-on-Tyne	Silos of ferro-concrete	60,000
Manchester Grain Silos	„ „	55,000
Grain Silos at Silvertown	Ferro-concrete	18,000
Eagle Oil Mills Co.—		
Eagle Oil Mills and Bon Accord Mill Silos	Silos of wood with steel bottoms	33,133
W. Gilyott & Co.'s Wilberforce Warehouses—		
No. 1. Garrison Side, Old Harbour, Hull	Floor warehouses	65,000
No. 2. High Street, Old Harbour	„ „	20,000
No. 3. High Street, Old Harbour	„ „	15,000
The Riverside Milling Co., Ltd.—		
Glasgow Riverside Granary	Silo warehouses	23,000

THE WAREHOUSING OF GRAIN

755

Name of Owner and Title of Granary.	Material Used and Nature of Granary.	Capacity. Qrs.
Great Central Railway Co.—		
Immingham Dock Granary - - -	Silos and floor granaries of ferro-concrete - - -	93,333
A. Guinness, Son, & Co., Ltd., Dublin—		
Malt Stores, St James' Gate Brewery -	Silos of brick and concrete -	125,000
Hurtley & Sons, Ltd.—		
Wilmington Flour Mills, Hull - - -	Silo warehouses - - -	24,000
John Jackson & Sons, Ltd.—		
Ordsall Dock Grain Silos - - -	Silos of ferro-concrete - - -	45,000
Lancashire and Yorkshire Railway Co.—		
Silo Granary, Wyre Dock, Fleetwood -	Silos of timber - - -	150,000
Leith Grain Warehousing Co.—		
Patmore Elevator and Grain Silo - - -	Silos of timber - - -	125,000
Liverpool Grain Storage and Transit Co.—		
Nos. 1 and 2 Alexandra Grain Warehouses	Silos of brick - - -	373,333
London and South-Western Railway Co.—		
Southampton Dock Granaries - - -	Floor warehouses - - -	304,000
Manchester Ship Canal Co.—		
Manchester Grain Silo No. 1 - - -	Silos of timber and brickwork	186,666
Manchester New Grain Silo No. 2 - - -	Silos of ferro-concrete - - -	186,666
Salford Dock Granary - - -	„ „ - - -	210,000
Mersey Dock and Harbour Board—		
Liverpool Dock Granary - - -	Floor and silo warehouses of brick and ferro-concrete -	199,500
Birkenhead Granary - - -	- - - - -	233,730
North-Eastern & Hull & Barnsley Railway Company—		
King George Dock Granary, Hull - - -	Ferro-concrete - - -	40,000
Oldham Roller Mills Granary - - -	Silos of brick - - -	23,778
R. & W. Paul, Ltd., Ipswich Granary - - -	Silos of ferro-concrete - - -	32,000
Port of London Authority—		
East India Dock Granary - - -	Silos of timber with steel bottoms - - -	40,000
London and India Docks Granary - - -	Silos of timber - - -	25,000
Millwall Dock Granary - - -	Floor and silo warehouse of brick - - -	100,000
Royal Victoria Docks Silo - - -	Silos of timber and steel -	25,000
Surrey Commercial Dock Warehouses—		
North Side of Greenland Dock - - -	Floor granaries, built of timber	82,000
North Side of South Dock - - -	„ „ built of brick	141,000
South Side of South Dock - - -	„ „ „ „	48,000
Transit Silos on the Thames - - -	Silos of timber with concrete bottoms - - -	32,000
Joseph Rank, Ltd.—		
Rank's Grain Silos, Hull - - -	Silo warehouses - - -	20,000

Name of Owner and Title of Granary.	Material Used and Nature of Granary.	Capacity. Qrs.
Rishworth, Ingleby, & Lofthouse—		
Granary Swan Flour Mills, Hull - -	Silos of wood with iron hoppers - - - -	33,000
Sun Flour Mills Granary, Bromley-by-Bow -	Silos of timber - - -	32,013
W. Vernon & Co.—		
Silos at Mersey Docks - - - -	Hoppers of ferro-concrete -	40,000
Victoria Dock Silos - - - -	„ „ -	56,000

Since the capacities of the different granaries mentioned in this chapter are given, diversely, in bushels, quarters, or tons, it might be as well to state that a bushel of wheat is reckoned to be 60 lb. ; that there are 4 bushels to the sack ; a sack contains 240 lb. of wheat ; there are 2 sacks to the quarter ; while a ton of wheat is reckoned to contain 4.66 quarters.

From 1st January 1923 all grain is to be sold by the cwt. except c.i.f.

THE AUTOMATIC WEIGHING OF MATERIAL, ETC.

CHAPTER XLIII

THE AUTOMATIC WEIGHING OF MATERIAL

WHEN handling material automatically, it is often desirable to keep a record of its weight; also of the total tonnage dealt with, so as to check deliveries of coal, grain, etc. It is also essential to keep a record of the contents of vessels filled mechanically, as well as of silos, bunkers, and other receptacles.

Automatic weighing machines which are used as a means to this end may be classified under three types. In one the material is weighed at the point of receiving from or delivering to the elevators or conveyors which handle it, in which case it actually passes through a weighing machine. A second type of weigher is attached to certain kinds of conveyors, and records the weight of the passing load without bringing the material itself in contact with the hopper of a weighing machine. There is also a third type which is used for weighing material intermittently in larger quantities. There are advantages and disadvantages in each method.

In the first type, termed **Hopper Weighing Machines**, the record of the weight is more accurate. This is, of course, an important matter if material of a valuable nature is being handled, but these machines have their limitations. To begin with, the material to be weighed must be of a fairly uniform size, that is to say, big pieces must not be mixed up with small particles. Then again, with these machines considerable headroom is necessary, which is not always available, as a stationary hopper must be provided into which the elevator or conveyor can deposit the material before feeding it into the weighing machine, and there must also be a second hopper beneath the weighing machine to receive the material leaving it. In addition to these two hoppers, the height of the weighing machine itself must be taken into consideration. This difficulty may be overcome by the use of an elevator, but there is also the drawback incidental to the breakage of friable material, and the consequent production of dust. In the case of coal the last objection would probably be the most urgent.

The second type, termed **Continuous Weighing Machines**, will record with sufficient accuracy coal, ore, cement, etc., as it is passed along by a conveyor of the belt, tray, plate, or gravity bucket type. The driving mechanism derives its motion from the conveyor itself, so that the record is not deranged by any variation in the speed of the conveyor. These machines require no extra headroom, produce no dust, and are not calculated to triturate the most friable material; but on the other hand, the record obtained is not so reliable as that of the hopper weighing machines.

The action of the first and second types is more or less continuous, as a constant stream passes through or over both kinds of weighing machines. Even with a hopper type the delivery can be made to a certain extent continuous.

The third type, termed **Intermittent Weighing Machines**, are for the purpose of weighing material contained in skips, buckets, or trucks, which, during the conveying process, pass a certain point where the weighing apparatus is stationed. They are used in connection with ropeways, mono-railways, and telfers, and may be arranged so that the load is stopped in its progress during the weighing operation, or they may be non-stop weighers, where the weight of the load is recorded during transit. Such appliances can, however, only be used successfully when the tare of the receptacle is known and has been adjusted to exactly the same in all the units which may be used for the conveyance of the load. The weighing machine itself generally weighs each separate lot, and adds the successive weights up to a total.

In selecting a weigher it is, of course, necessary to take all these conditions into consideration. Broadly speaking, it may be said that the hopper weighing machine is most suitable for grain, seeds, small coal, etc., the continuous weighing machine for coal and minerals, whilst with the intermittent weighing machine material of any kind may be conveyed in the receptacle passing over the weigher.

HOPPER WEIGHING MACHINES

The "Chronos" Automatic Grain Scale.—This was the first machine for the purpose of automatic weighing, and is the design of Messrs Reuther & Reisert, of Hennef-on-the-Sieg, Germany (see Figs. 1112 and 1113). So far as this country is concerned this machine is only of historical interest.

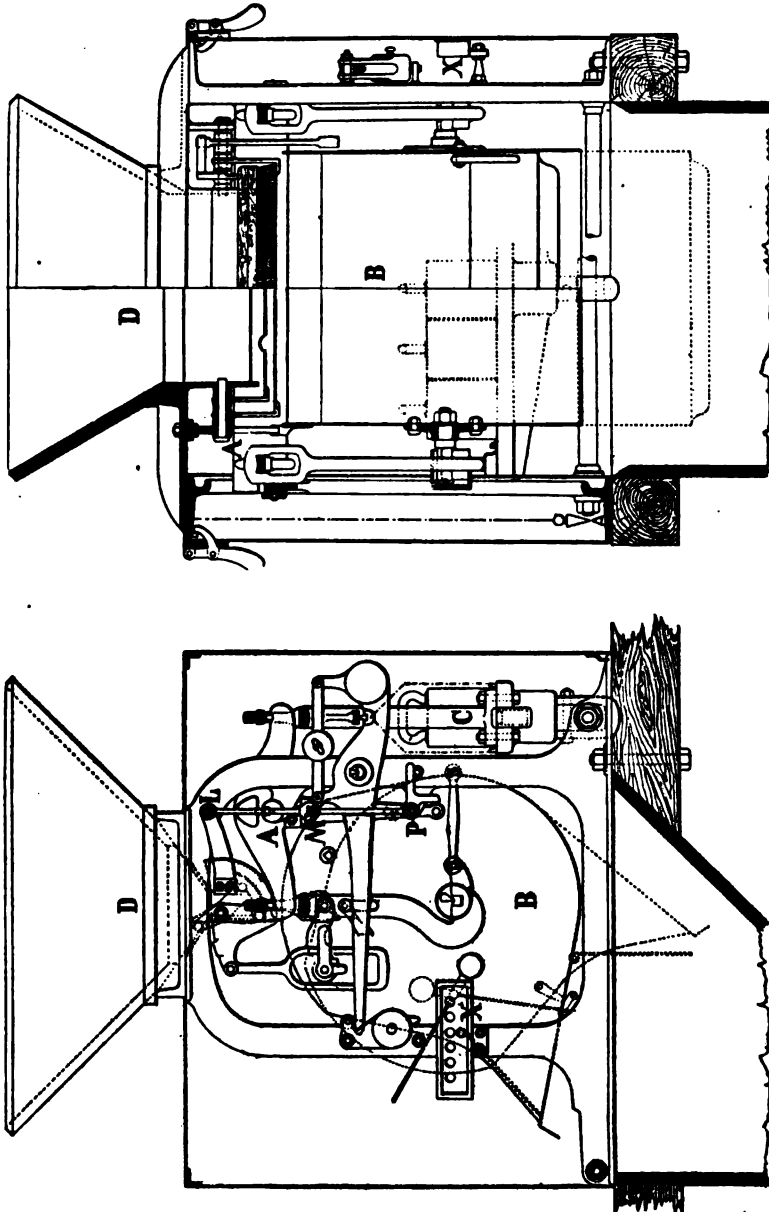
This weigher consists essentially of a beam scale *A*, of the usual kind, with arms of equal length, to one of which is suspended the weight *c*, and to the other a skip *B* for the reception of the grain, such a skip being capable of rotation on an axis, and being provided with two apertures for the respective operations of receiving and discharging, whilst from the other arm there also hangs a beam board which will take any ordinary kind of weight.

Over the recipient is placed a hopper *D*, underneath which play two valves, or rather gates, which regulate the flow feed. The grain pouring through the hopper soon fills up the recipient *B*, until suddenly the upper gate partially closes, thus shutting off the greater part of the feed, and letting in only two thin streams of grain, which together make up the exact weight set on the beam board. As soon as that point has been reached, a stud attached to the pointer of the beam scale comes in contact with a toggle joint *P M L*, which serves to support the second flap and bends the former down. The effect of this is to completely close the inlet, while simultaneously a hook, which has kept the recipient in an upright position for taking in the feed, is released. The skip then tips forward about 40°, this movement being sufficient to empty it of its contents, but as soon as this has been accomplished it regains its former position, the index *x* registering the weighing, whereupon the two inlet valves are opened, and it is again held fast by the hook. With the re-entry of the feed the operation already described is repeated. Each revolution of the skip, and therefore each discharge of a given weight of grain, is registered on a dial attached to the front of the scale. The two illustrations, Figs. 1112 and 1113, give a clear idea of the movement of the skip *B*, as well as of the action of the "Chronos" machine.

To reduce friction to a minimum and to ensure smooth work, it has been the aim of the makers of this machine to shorten as much as possible the arc traversed by the skip in its tripping motion, hence it had to be provided with an outlet distinct from the inlet. Moreover, the recipient has been so shaped and hung, that while the grain, seeds, or other materials are being fed through the inlet, the bottom of the skip

remains in a horizontal or nearly horizontal position, while, during emptying, the angle is slightly more than the angle of repose of the grain.

The weight of the outward flap is sufficient to keep the discharge opening shut



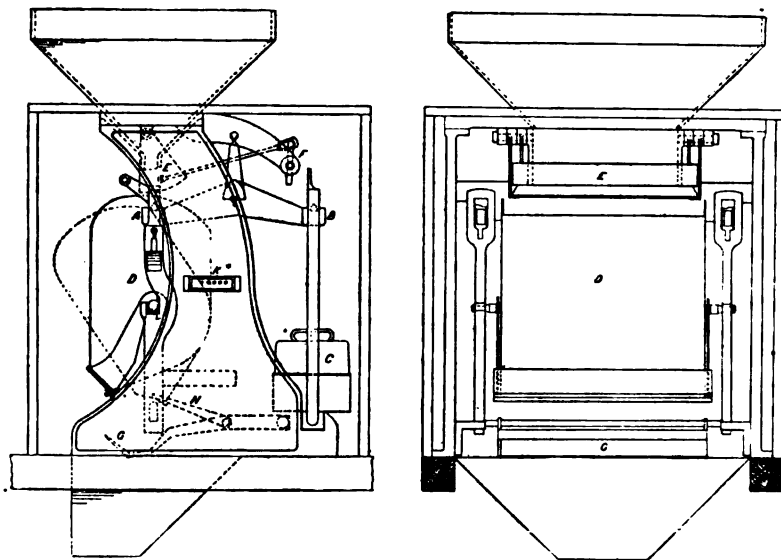
Figs. 1112 and 1113. "Chronos" Grain Scale, showing Action of Skip.

during the filling operation, while it swings forward and allows a free passage to the discharging grain as soon as the angle is enlarged by the revolution of the recipient. Meanwhile the discharge gate has fulfilled its appointed function in preventing

any portion of the grain from spurting outwards and escaping before the right time.

The setting of the scale appears to be a very simple operation. By a turn of a small lever the mechanical parts of the weigher and the beam scale are entirely disconnected. The beam will then swing loose like the beam of an ordinary scale, while the pointer will play freely whether the board be weighted or not. It is thus easy at any moment to test the weigher by means of its own scale, and this operation can be effected in a few seconds without in any way interrupting the work. If any discrepancies should be manifest in the weighing, they can be corrected by the adjustment of a small weight, and when once this weight has been set in its proper position, the machine will weigh accurately and continue to do so.

If desired, the whole apparatus can be covered by a sheet-iron casing, which will



Figs. 1114 and 1115. "Nomis" Automatic Beam Scale.

leave no part exposed except the glass face of the dial register. The casing can then be locked, thus effectually removing the possibility of any tampering.

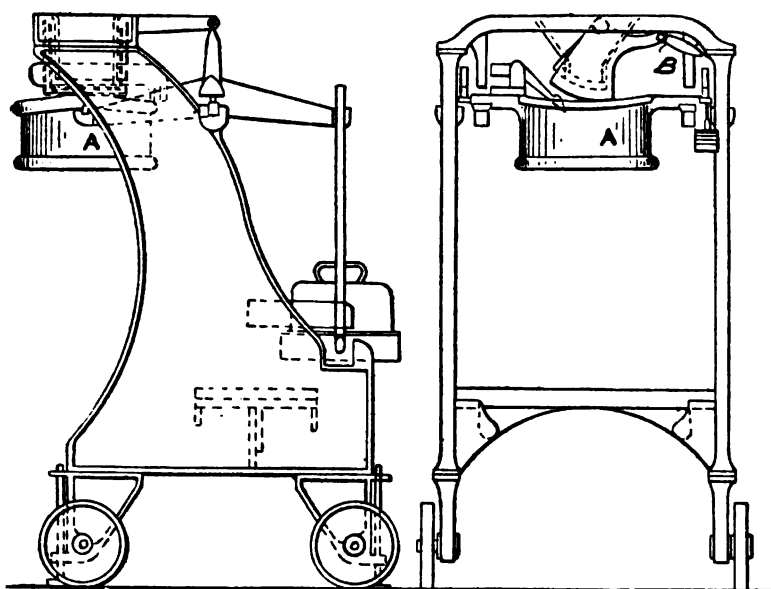
This machine is built in eighteen sizes, for charges from 12 to 3,300 lb. of grain, and with a corresponding capacity of from 32 to 3,240 cwt. of grain per hour.

The "**Nomis**" Automatic Beam Scale is built by Richard Simon & Sons, Ltd., Nottingham. It is of very simple construction, and is illustrated in Figs. 1114 and 1115, which show front and side elevations of the machine with the inlet and delivery skip. The side elevation shows the grain hopper both in its normal position and when empty, and also in dotted lines the position it takes during discharge.

This machine is a beam scale, having equal arms *A B*, with a standard weight *c* suspended from the end *B* of the beam, and the receptacle *D* hanging from *A* at the opposite end. Above is a valve arrangement *E*, which admits grain and other similar substances, and also cuts off the flow when the correct weight has been admitted. The mechanism used to obtain this result is very simple. A side weight acts, together with the skip *D* and the inflowing weight of grain, to overcome the inertia of the dead weight

on the other arm, and to shut the first of the two valves, so that the inflowing grain is reduced to two small streams when the correct weight has been nearly reached. The adjustable side weight compensates for the stream of grain in the act of falling at the moment of closing the valve. The final cut-off is caused by the rising of the arm B of the scale with the weight C as the grain recipient descends.

A steel pawl lifts the crank F coupled direct to the valve E, so that as soon as the crank is over the dead centre, the weight of the valve is called into action to close itself. After closing, the valve moves forward sufficiently to release the catch supporting the skip D, which, being pivoted somewhat below its centre of gravity, immediately tilts, and in so doing uncovers the discharge opening at the bottom through which the grain leaves the bucket. The discharging wheat strikes a rocking plate G, secured to the frame of the machine. This brings down a hook H, which holds the bucket in



Figs. 1116 and 1117. Simon's Sack-Filling, Weighing, and Recording Machine.

position until it has emptied itself, after which it is released and swings back to be refilled, closing itself and opening the inlet valve by its momentum, while simultaneously it actuates the counter K and so registers the weighing.

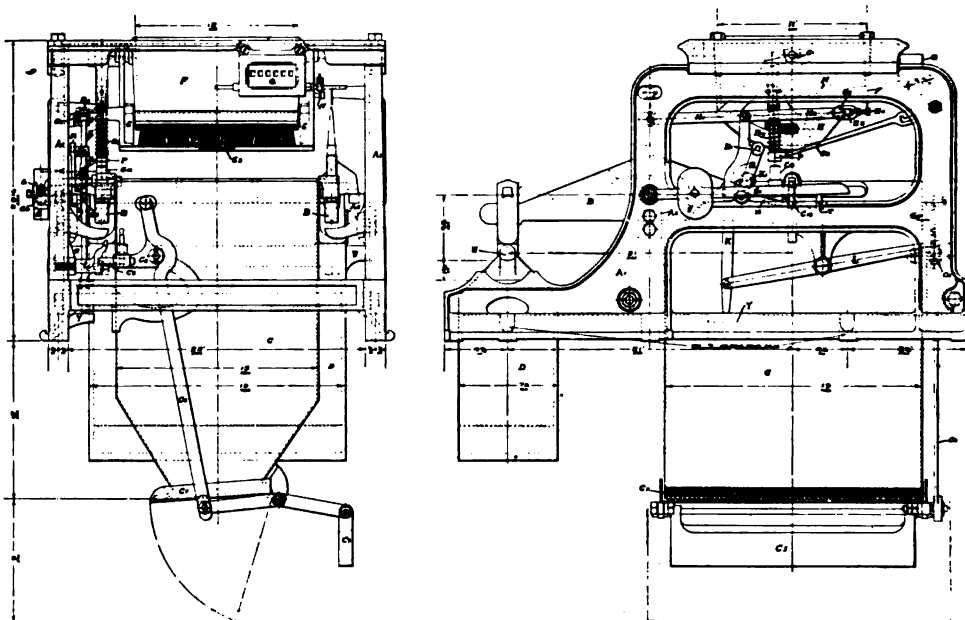
Should the discharge spout from the weighing machine become blocked, owing to it weighing more than the shoot below can take away, the machine stops automatically and recommences work as soon as the accumulation has subsided. The short substantial beam of the machine secures rigidity and reduces vibration, which means that the oscillation during the weighing is reduced to a minimum. It also facilitates a quicker succession of weighings, as many as four per minute having been accomplished. The machine is chiefly used for weighing grain and seeds. It is built in ten sizes, having capacities of 2 to 500 qrs. per hour, and ranging in height from 12½ to 89½ in. for the different sizes.

Simon's Automatic Sack-Filling, Weighing, and Recording Machine.

—A modification of the machine just described is illustrated in Figs. 1116 and 1117.

Instead of the weighing hopper, a sack is attached to the machine which serves for sugar, flour, coffee, rice, grain, seeds, etc., ordinary standard weights being used. It is claimed for it that it is a great labour-saving device, and is accurate to an ounce in 2 cwt. There is a counter in connection with it which records the number of sacks thus filled and weighed. All that the attendant has to do is to attach the empty bag to the cylinder A, and pull down the handle B, whereupon the sack is automatically filled with the correct weight. It can then be tied up and another one attached. This portable weighing machine should be of great service under silo floors, where grain from different silos has to be filled into sacks, as it can be put in position under any silo, and connected by a sleeve or temporary spout with the hopper bottom. It is also made for suspending under the silos.

Avery's Automatic Grain Scale.—This automatic weigher is built by W. & T.



Figs. 1118 and 1119. Avery's Automatic Grain Scale.

Avery, Ltd., Birmingham, England. The diagrams, Figs. 1118 and 1119, show the scale when empty. A_1 and A_2 are the side frames in which are fixed the main bearings A and A_0 ; in these rest the knife edges of the beam B having suspended at one end the iron box D, at the other end the receptacle C in which the grain is weighed, and so arranged that the box D exactly balances the hopper C. The former is constructed to hold the required quantity of dead weights, and being made with a sloping top, no dust etc., can lodge thereon. It also has a hinged lid which can be fitted with a lock to prevent any tampering with the weights.

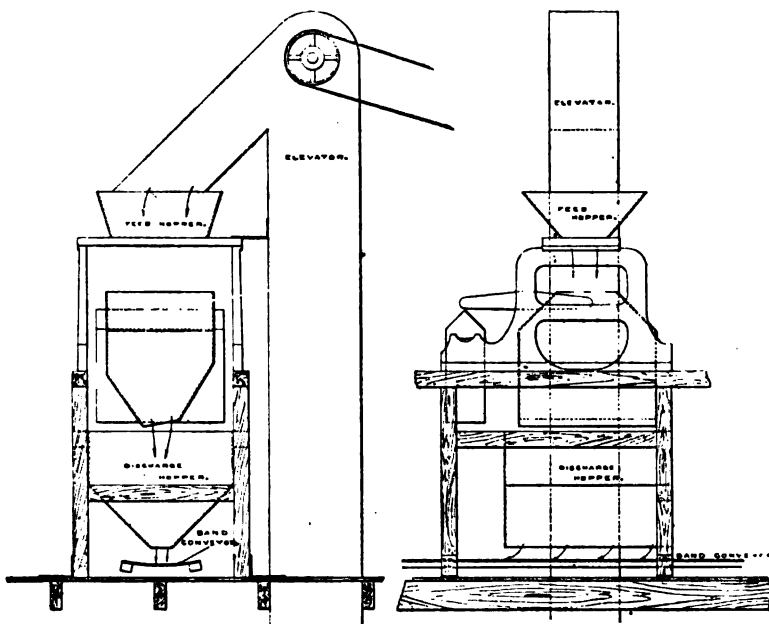
The weigh hopper C has a door C_1 at the bottom, which is automatically opened and closed when required.

The supply of grain is regulated from the shoot F by a weighted valve G hinged at G_1 with an aperture G_2 in its front edge. A pin G_3 attached to the valve G works in the slot H_3 of the lever H_2 so that when the locking levers H_1 and H_2 are down (as shown in Fig. 1119) the valve G is prevented from opening. These locking levers

H_1 and H_2 are connected with the lever L by a weighty rod K fitted with a steel roller K_1 , which, when the rod is raised, rests on the knife edges or roller M_1 fastened to the trigger M , the latter being so pivoted as to swing underneath by its own weight.

The door C_7 , at the bottom of the weigh hopper C , is kept shut during the weighing operation by the bar C_3 attached to the toggle C_8 . This toggle is pivoted to the hopper, and fitted with a striking bolt C_9 , which, when the scale is required to weigh automatically, is drawn out until it overhangs the lever L . The door is so arranged that when open the weights C_5 and C_6 exert only a slight tendency to close it, thus a little of the grain at the top will keep it open, and automatically stop the machine from working until the weigh hopper C is empty.

The action of the scale is as follows: On weights to the required quantity being



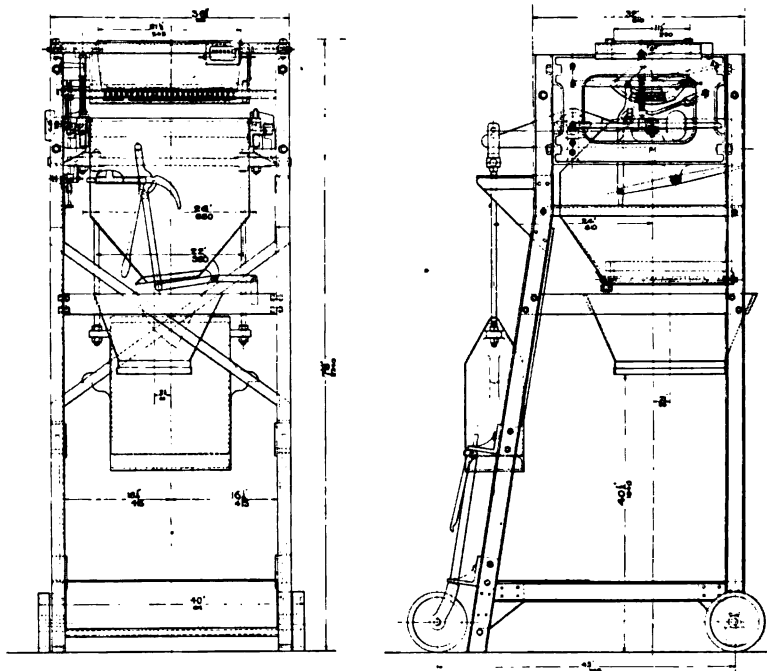
Figs. 1120 and 1121. Avery's Weighing Machine for Grain, *in situ*.

placed in the box D , that end of the beam B is depressed until the projections v_1 on the box D rest on the side frames A_1 and A_2 ; the other end of the beam rises, and by means of the projection C_{12} catching under the pendant P attempts to lift the valve G , but being prevented by the locking levers H_1 and H_2 , it only compresses the pendant-spring B_2 . (This also causes the box D and weights to descend gently without any jar to the machine.)

On the free end of the lever L being depressed, the other end raises the rod K and breaks the locking joint formed by the levers H_1 and H_2 ; this releases the valve G which, owing to the pressure of the spring B_2 , flies wide open, lifting the levers H_1 and H_2 with it, and admits a full stream of grain from the shoot F ; this goes on until the weight of the grain in the hopper C , assisted by the weight of the valve G , depresses the beam B until it no longer supports the valve, which swings to again as far as it is allowed by the pin G_2 in the slot H_3 of the lever H_2 .

The levers H_1 and H_2 are supported by the rod K resting on the knife edge or

roller m_1 in the trigger m . The only grain now coming into the scale is what can flow through the small aperture c_3 in the valve c , and this amount can be adjusted by means of the screw H_4 regulating the length of the slot H_3 . This dribble of grain goes on until the weight of grain in the hopper c is equal to the dead weights in the box D , when the beam comes down to the horizontal, and by means of a projection c_{10} draws away the trigger m from beneath the rod k which falls on to a stop and brings the levers H_1 and H_2 with it; these by means of the pin c_2 completely shut the valve c and lock it as before. The falling of this rod k raises the free end of the lever L which, by catching the striking bolt c_8 , opens the door c_7 ; this remains open until all the material has been discharged, when the door swings to again and the striking bolt c_8 coming down depresses the lever L , which starts the whole operation over again.



Figs. 1122 and 1123. Avery's Automatic Weighing Machine for Sacking-off Purposes.

It will be noticed that when the weight of the grain in the hopper c exactly balances the weights in the box D , the valve c immediately shuts, but the grain in suspension at the time falls into the hopper and would be overweight were it not compensated for by an adjustable weight s on the bar s_1 which rests on the beam during the weighing operation, but afterwards catches a stop on the frame so that the beam finally swings clear of all the working parts, and conclusively proves that there is a perfect balance.

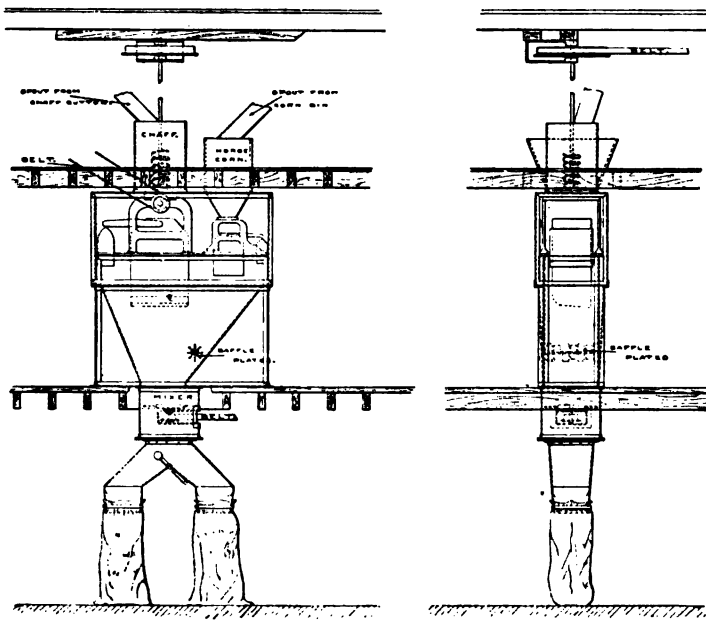
The ordinary register or counting apparatus Q is so attached to the lever L as to keep a record of the number of weighings performed by the scale.

Figs. 1120 and 1121 show one way in which the Avery Weighing Machine is installed in warehouses, etc., for the purpose of weighing grain in bulk. The grain is received, elevated to the top of the warehouse, and carried by means of band or other conveyors to the silos. The illustration shows the elevator, and also indicates the

position of the weighing machine between this apparatus and the conveyor which further disposes of the grain.

The scale is placed on a suitable staging, and fitted with a feed hopper above and a discharge hopper below, each of which is of a capacity slightly in excess of that of the weigh hopper of the machine. The spout from the elevator leads into the feed hopper, and after the grain has passed through the scale and been weighed and registered, it drops into the discharge hopper, whence it falls gradually on to the conveyor which distributes the grain to the silos. The opening in the hopper can be so adjusted as to feed the conveyor gradually.

This machine is built in twenty-four sizes from 12 to 96 in. in height, the respective capacities for the different sizes being from 20 to 12,000 lb.



Figs. 1124 and 1125. Avery's Weighers for Chaff and Grain.

Avery's Automatic Weighing Machines for Sacking-off Purposes.—

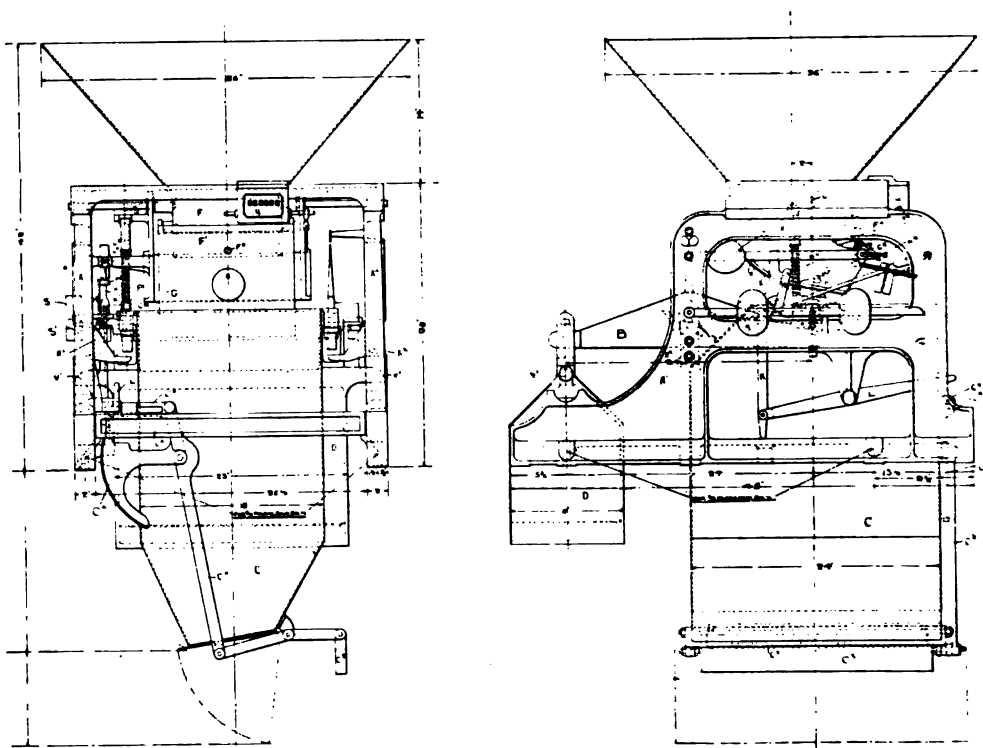
The Automatic Net Weigher (see Figs. 1122 and 1123) is built on the lines of the machine described above, but is specially constructed to meet the requirements of those who prefer to have their material weighed net, and then delivered into sacks. The machine is a great labour saver; one man can work it, filling, weighing, and counting automatically about four sacks per minute.

The machine cannot discharge until the man has the empty sack in position ready to receive the load, when he simply touches a lever which causes the machine to discharge and make another weighing ready for the next empty sack. Every discharge of the machine is registered, thus keeping an accurate record of the number of sacks sent out. Each weighing balances as soon as the grain is cut off; the operator sees this balance.

Avery's Automatic Gross Weigher possesses the chief features of the Net Weigher, but it weighs the sack and material together. The speed of working of this machine is not so quick as the Net Weigher owing to the time necessary to attach the empty

sack to the bag holder by a strap and clasp. Both machines being portable they can be moved about from place to place.

Avery's Automatic Machine for Provender Mills.—The automatic weighing of chaff is admittedly difficult, because the extremely light nature of this material necessitates a large quantity in the weighing hopper before any weight and consequently power can be obtained, and also because chaff from its nature will not run readily in spouts and hopper-shaped receptacles. For these reasons many forage and provender mills have hitherto employed measuring devices for chaff, the grain being added in the proper proportion by means of weighing machines.



Figs. 1126 and 1127. Avery's Automatic Scale for Coal, etc.

The lettered description for Figs. 1118 and 1119 (Avery's Automatic Grain Scale) applies to this illustration also, with the exception that for weighing small coal the aperture during the dribble period is arranged between a hinged flap F^1 and the valve G . The adjusting screw F^2 is for varying the size of this aperture.

Figs. 1124 and 1125 show an installation in which Avery weighers are used both for chaff and grain; in this case there are two machines. Such installations are now at work both in this country and abroad, notably at the Midland Railway Co. Provender Stores at Oakham, where there are four complete sets. When it is desired to weigh chaff it is usually for the purpose of obtaining the correct percentage of chaff and corn in a mixture of the two for feeding purposes. The small machine used for weighing the corn is the ordinary type of weigher as already described, and is so connected with the chaff scale that they discharge together.

Above this chaff scale is a stirring device which ensures an even flow of the material from the hopper to the scale. This hopper is connected by spout with the chaff-cutting machine. Just below the chaff hopper is a small pulley driven by a belt, which is attached by a spindle to the valves in such a way as to automatically aid in lifting them when required by the machine. Both machines simultaneously discharge into the large hopper below, and right on to the mixer, which consists of a rapidly revolving spindle studded with spikes and driven by a belt as shown. This is to prevent the corn, owing to its greater weight, from falling into the sack quicker than the chaff. The inside of the hopper is fitted with a row of baffle plates which can be so adjusted that the corn discharges into the mixer in a more uniform stream than would otherwise be the case. From this mixer the provender falls into a breeches piece and thence into either sack as required. These machines are best fitted with

Fig. 1128. Two Avery Automatic Boiler Scales in an Electricity Works.

glass-panelled covers, which not only obviate any escape of dust, but also prevent any tampering with the mechanism.

Avery's Automatic Scale for Weighing Coal, Coke, Minerals, and Similar Materials.—This weighing machine is very similar to the one for grain already described, and is illustrated in Figs. 1126 and 1127. A machine with a hopper capacity of 2 cwt. per discharge is usually installed for weighing small coal in connection with bunkers, etc. It is worked by gravity alone and requires no power either electrical or mechanical to operate it. The machine is fitted with locking gear which prevents any coal passing through unweighed.

These automatic coal weighers are chiefly employed in boiler-houses, and the majority of the leading electric power stations at home and abroad are now equipped with these machines. In particular the Glasgow Corporation may be mentioned as among the users of the Avery machine; they have installed some forty of them, two of which may be seen in Fig. 1128.

By means of these weighers the mechanical stokers are automatically fed

with coal from the bunkers above, and a record is kept of the total consumption of fuel by each boiler. As the coal passes through the scale, its weight is duly recorded; it then falls into the discharge hopper below, which feeds the stoker hoppers.

Charge after charge is weighed and delivered to the stoker hoppers until the spouts leading to them are quite full, whereupon the weighing machine stops automatically. As soon, however, as sufficient coal has been used by the

stokers to clear the shoot, the weighing machine will recommence work, and in this way always adapts itself to the consumption of coal.

Instead of fixing a machine beneath each coal bunker, another method is to have one large machine fitted on a travelling frame which runs on rails overhead and can be brought under each bunker as required. The travelling machine is moved along on flanged wheels on a track underneath the bunkers by means of a chain drive actuated from the boiler-house floor. A machine of this type is illustrated in Fig. 1129.

Automatic coal weighers of larger capacity, say half-ton, or one or two tons per discharge, are also supplied for weighing the intake delivered from barges, railway trucks, etc.

Fig. 1129. Installation of Avery Automatic Travelling Boiler Scales.

The "Simplex" Grain Scale.—This machine is illustrated in front elevation and side view, Figs. 1130 and 1131. Its mechanism is simple, the working parts are

few, and there is not much that is likely to get out of order. A machine weighing 100 lb. at a charge will make about three weighings per minute. It will be seen from the drawing that there is a solid iron ball weight *A*. In a machine taking charges of 100 lb., this ball will weigh 50 lb., the same as the weight *B* underneath. The receiving hopper is on the opposite side of the weigh-beam, and when it has received its 100 lb. of wheat from the feed hopper *C*, it tilts up the runners on which the ball *A* rests, and at the instant the ball moves towards the hopper on its runners it comes in contact with a semicircular lever *D*, which cuts off the supply; while by the time it has reached the hopper it touches another lever *D'*, which releases the discharge gate *E* at the bottom of the hopper and allows the grain to escape. As soon as the skip is empty the runners of the weight tilt up again and the ball begins its return journey. Immediately the ball commences to move in the opposite direction the recipient closes again through the release of a lever *D'*, and as soon as the ball reaches the terminus it turns the feed on by means of the first-mentioned lever *D*.

There is no time wasted between the weighings, but the most remarkable point about the machine is this, that it works altogether noiselessly, there being no clicking and engaging of levers in catches, as is the case with many other weighing machines. The discharge door *E* is practically locked during the drop of the skip, and as there is no connection between the feed gate and the skip, there should be no danger of the discharge gate getting blocked, as the feed gate cannot open during the discharge on account of the heavy ball not being able to return and open the gate until the grain in the hopper has been removed.

The "Simplex" weighing machine is built in six sizes, the respective machines being for charges weighing from 20 to 100 lb., and the machine occupies a height of only 18 in. to 2 ft.

CONTINUOUS WEIGHING MACHINES

"Blake-Denison" Continuous Weigher.—This machine is so constructed that it will weigh material in the course of being conveyed. Thus a "floating" section of the conveyor is also made a portion of the weighing machine. The principle upon which it is constructed is that of weighing the contents of a given length of conveyor at intervals of time corresponding with the travel of such length, and automatically recording such weight. Thus, if the machine is made to weigh 10 ft. of conveyor at a time, it will weigh and record every time 10 ft. has passed, and so every section will be weighed consecutively, with, it is claimed, a maximum error of $\frac{1}{2}$ per cent., and the continuous totalised record can be read as frequently as necessary.

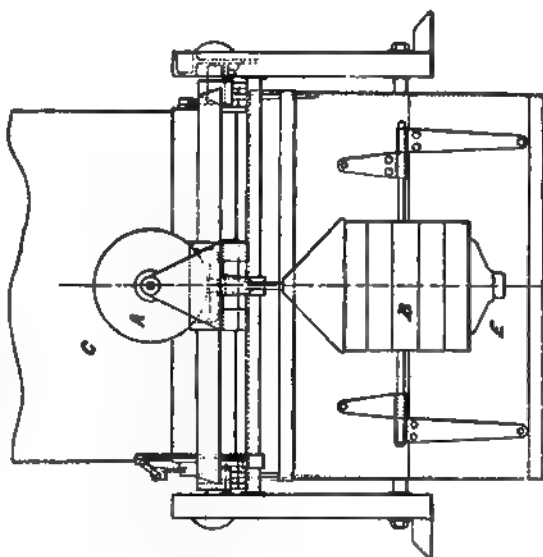
The special features of the weigher are:—

1. A steelyard balanced to suit the unloaded conveyor and arranged to rise accurately in proportion to the load.
2. A gripping device to hold the steelyard fast at suitable intervals.
3. A measuring gauge or quadrant to ascertain the weight indicated by the steelyard when so held.
4. A recording mechanism to show the result.

The section of the conveyor to be weighed is supported on a roller or other suitable device which is suspended from the vertical rod of an ordinary multiple lever platform weighing machine.

To balance the load upon the conveyor as it passes over a roller, the mercurial dashpot is used, the hollow piston of which is suspended from a fixed point on the lever, in place of the usual sliding weights on a graduated lever (see Fig. 1132).

The dashpot consists of a carefully turned vertical piston, its lower part dipping



Figs. 1130 and 1131. "Simplex" Grain Scale.

into a bath of mercury, and loaded sufficiently to cause it to be submerged some distance in the mercury before the machine is in balance unloaded. It will be seen that when the heavier load comes on the machine the lever rises, and the greater portion of the piston comes out of the mercury until the balance is again established.

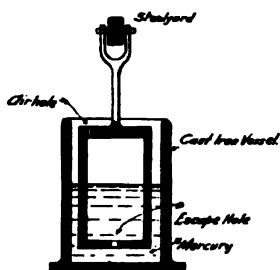


Fig. 1132. Dashpot.

At the same time a small hole in the hollow piston allows the mercury to escape comparatively slowly. This arrangement acts as a dashpot for steadying the oscillations of the lever when the latter takes up a particular position due to the weight of the length of conveyor and the load on it.

The registering mechanism is shown in Fig. 1133. The cam A causes the levers E to move to the right, and this thrusts the steelyard F of the weighing machine against a surface so roughened as to prevent it from slipping. Another cam then permits the registering quadrant (which is moved to the right by a system of levers actuated by gravity) to move freely to the right, a movement which is only checked by the clamped steelyard F. As the quadrant moves to the right the ten pawls ride over the teeth of the registering wheel. There is a brake on the registering wheel which acts immediately the quadrant is at its left-hand limit. This is to prevent the momentum of the wheel from carrying it on.

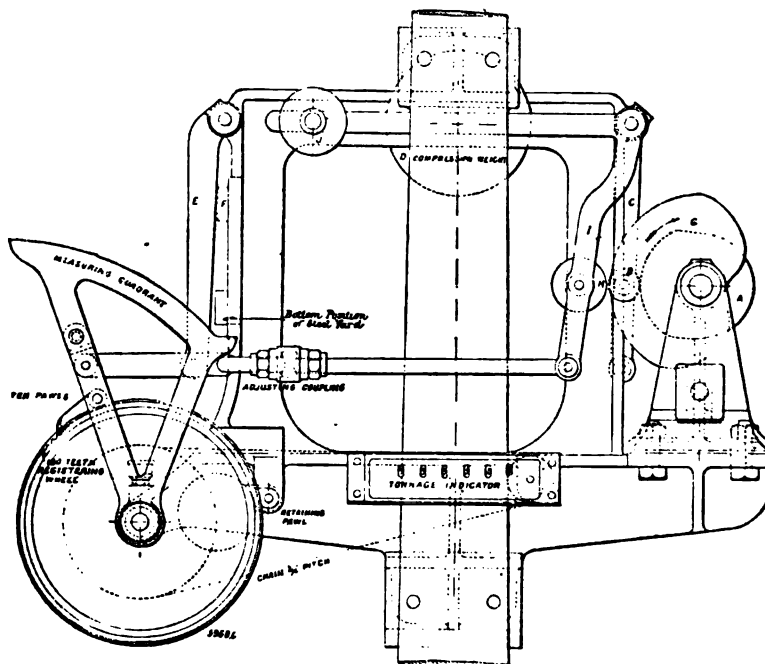


Fig. 1133. Diagram showing Cam and Quadrant Arrangements as used with the "Blake-Denison" Weighing Machine.

The cam C causes the quadrant invariably to move back to the same left-hand limit, the pawls engaging and carrying the registering wheel with the quadrant.

It is therefore evident that the rotation of the registering wheel is dependent upon the extent of the movement of the quadrant to the right. This is determined by the position of the weighing lever, and this again by the weight on the machine. The two

cams A and C are on one shaft, and this is driven by bevel wheels from one of the conveyor terminals.

Each of the ten pawls is one-tenth of the pitch of the teeth of the ratchet wheel in advance of the next to its left. The maximum slip is therefore one-tenth of a tooth. In the latest machines a conical clutch is used instead of the ratchet wheel and pawls; this improvement eliminates all loss of motion and ensures still greater accuracy. In the machines already built the cycle occurs every five seconds, and is as follows: The steelyard is free for about three seconds, during which time it assumes the position proportional to the load upon that section of the conveyor which is supported by the weighing machine. It is then gripped by the action of the first cam, the second cam immediately allowing the measuring quadrant to move forward until it touches the steelyard, where it remains until pushed back by the further motion of its cam; the first cam then releases the steelyard. The weight is recorded by the backward motion of the measuring gauge. There are thus four motions—gripping, measuring, recording, and releasing—which occupy somewhat less than half the time of the whole cycle. It will be readily understood that when the steelyard is at its lowest position it must touch the measuring gauge at its stationary position, as there can be no motion of the latter if the steelyard indicates no load. It has, however, proved impracticable to allow the steelyard to touch the gauge at the lowest position, for two reasons:—

Firstly, it is difficult to adjust the steelyard so accurately that it touches the gauge and yet exercises no pressure upon it.

Secondly, the vibration of the conveyor gearing, etc., sets up oscillations in the steelyard which would allow the gauge to occasionally gather a few pounds and so introduce an error. This difficulty has been overcome by balancing the steelyard at a point somewhere above zero, and then subtracting a corresponding amount of weight each time a weighing takes place.

Thus, for instance, if the steelyard is so balanced as to remain in a position corresponding to $\frac{1}{2}$ cwt., when there is no load on the conveyor, the measuring gauge will register on its return stroke $\frac{1}{2}$ cwt. each time. But if a device is introduced for deducting $\frac{1}{2}$ cwt. from the register each time, the motions cancel each other, and the register remains unaltered. The device referred to consists of a set of wheels, two of which gear with a pinion carried upon an arm of the wheel driving the counter (see Fig. 1134).

If the two bevel wheels move an equal amount, but in opposite directions, the result will be that the pinion is merely revolving upon its axis. But if one of the wheels moves more than the other, the pinion will be driven forward or backward accordingly, and will carry the registering wheel with it. To the spindle of one of these bevel wheels is attached a ratchet wheel having a suitable number of teeth—where the lever is balanced at $\frac{1}{2}$ cwt. the number would be forty—while a lever and pawl operated from the camshaft drives the ratchet wheel one tooth every cycle, deducting a corresponding amount from the register. The other bevel wheel is driven from the measuring gauge.

The counter or register thus operated records the quantity of material passed over the conveyor during a given period. The measuring gauge or quadrant consists of a vulcanite plate securely fastened to a light steel frame. The frame encloses a finely divided steel ratchet wheel, and carries a set of ten pawls of different lengths engaging

Fig. 1134. Registering Device as used with the "Blake-Denison" Weighing Machine.

the said wheel. This confines, as has already been remarked, the error due to loss of motion between the pawls and the wheel to one-tenth of a tooth. There is also a set of ten retaining pawls attached to a fixed stud on the body of the machine. The large steel ratchet wheel is keyed upon a spindle connected with the registering counter, while the frame carrying the pawls swings freely upon the boss of the wheels. This frame has a reciprocating motion imparted to it by means of the cam previously described. This machine is built by Messrs Samuel Denison & Son, Ltd., Leeds.

The Merrick Weightometer.—This continuous weighing machine consists of weighing levers and steelyard or beam, similar in principle to those of the usual platform scale, but of such design that a short length of the working strand of the conveyor is floating and suspended from the weighing levers. Fig. 1135 shows such a machine applied to a portion of a band conveyor, whilst Fig. 1136 gives a diagrammatic sketch of the integrator.

The weight of the load on the suspended portion of the conveyor, regardless of its distribution, is at any instant automatically counterbalanced by the buoyancy of a cylindrical iron float suspended from near the long end of the weighing beam, and

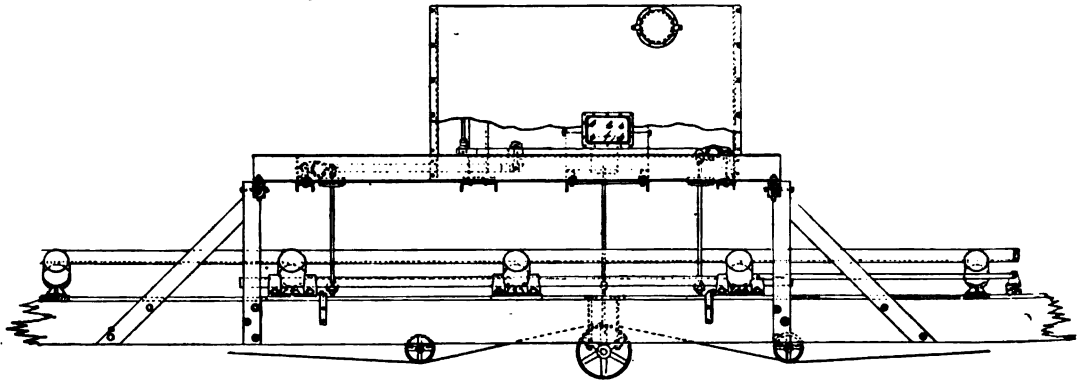


Fig. 1135. The Merrick Weightometer in connection with a Band Conveyor.

partially immersed in a bath of mercury. Any increase or decrease of load on the levers will either raise or lower the float in the mercury until the loss or gain in buoyancy compensates for the variation in load.

The function of this float is to ensure the movement of the beam from its zero position (that is when the conveyor is empty) being proportional to the weight of material at any instant on the suspended portion of the conveyor. The extreme end of the beam is connected with a totalising mechanical integrator, which derives its other factor from the travel of the conveyor by means of suitable gearing from a jockey pulley on the return belt, or a sprocket wheel if on a chain-driven conveyor.

The integrator continuously totalises the product of two quantities, one proportional to the weight of material suspended, and the other to the travel of this material. The result, therefore, represents the total weight of material, and is plainly indicated by a register in units and tenths of units of either ordinary or metric tons.

For cases where the material handled adheres to the conveyor in a varying amount, an attachment is added which automatically counterbalances the variable weight of the empty conveyor. This avoids frequent adjustment to meet the changes in the weight of the empty conveyor and material that may adhere thereto. A magnetic counter can be applied which will duplicate the reading of the scale register in an office or at any other point remote from the scale itself and present the record.

The Integrator.—This consists of an aluminium disc, around the periphery of which are mounted rollers *v* free to revolve. These have their axes tangential to the edge of the disc and form practically a continuous annular roller.

The disc *x* is fixed to a spindle and can revolve in bearings on the frame *z*. This frame is mounted with a bearing at either end, so that it can rotate around an axis coincident with the plane of the disc and at right angles to the axis of the disc. On one end of this frame *z* is an arm, the extremity of which is connected by a link to the long end of the weigh-beam. Thus any movement of the beam, caused by an increase of the load on the belt, tilts the frame through an angle, the sine of which is proportional to the vertical movement of the float and again proportional to the load on the suspended portion of the conveyor.

Four pulleys *u u*, *q q* guide a small endless belt *w* round the disc, and touching the rollers thereon at two points diametrically opposite. Pressure rollers *v* keep the belt and disc rollers in contact. A weighted take-up pulley *t* assures an even tension in the belt, and compensates for any stretch. The two pulleys *u u* are geared together and are driven by mitre gear from a bend or jockey pulley under the return belt. The belt driving the integrator thus travels at a speed proportional to that of the conveyor.

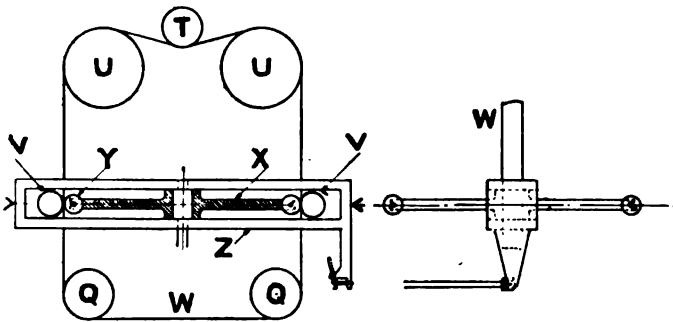


Fig. 1136. Diagram of Integrator of Merrick Weightometer.

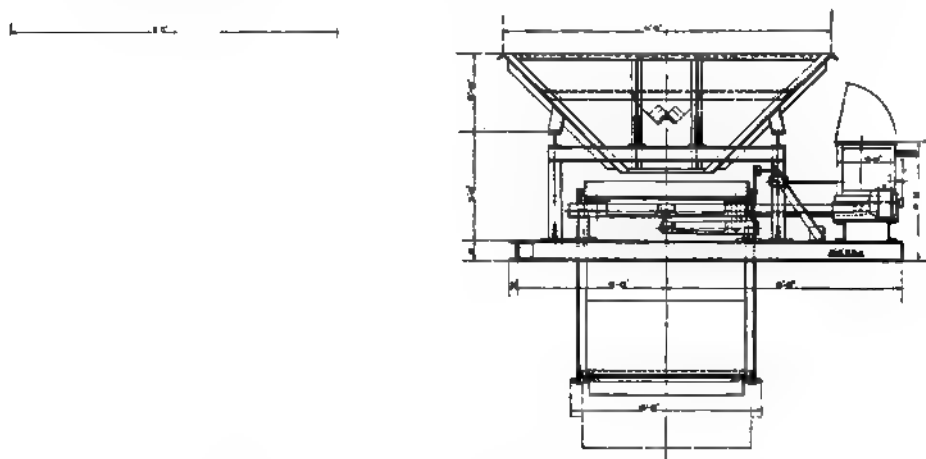
So long as the axes of the rollers *v* are parallel to the direction of the integrator belt, the motion of the latter will only affect them to the extent of revolving the rollers on their own axes. This condition corresponds with a zero position of the beam, that is, when there is no load on the conveyor. If, however, the beam is deflected by the loading of the belt, the frame *z* and disc *x* will be correspondingly tilted; this will incline the axes of the rollers *v* with respect to the integrator belt, then besides rotating them the belt will push the rollers sideways across its face at the rate proportional to their inclination. As the rollers *v* cannot slide on the disc *x*, they will rotate around its axis; consequently the speed of rotation of the disc is proportional to the deflection of the beam, the movement of the float, or the load on the conveyor. The amount of this motion is thus a measure of the weight of material carried by the conveyor during the period of observation. Thus the revolution counter mounted on the disc shaft will record and totalise the weight carried in any units for which the mechanism is designed.

A glance at the disc when the conveyor is running empty will determine whether the dead weight of the idlers, etc., plus the weight of the belt or buckets, is correctly balanced, so that the net weight of the material is recorded. Should the dial remain stationary, or move backward and forward between two constant limits of travel, the adjustment is correct. Should the dial make a plus or minus gain it is not, and the proper balancing is obtained by means of a weight on the steelyard. This weight

is carried on a screw and is similar to that on the ordinary platform scale, as the terminal screw moves the balance weight.

INTERMITTENT WEIGHING MACHINES

Avery's Patent Automatic Hopper Weigher and Totaliser (Figs. 1137 and 1138) consists of the Avery patent totalling mechanism attached to weighing levers which carry a hopper of sufficient capacity to contain the contents of a full grab or skip. The grab or skip discharges directly into a hopper, which is carried upon a rigid framework and supported independently of the machine. This hopper is constructed to take up the shock of the falling coal and to conduct the coal into a second hopper, which is part of the actual weighing machine. As the coal reaches the weighing hopper, the scale automatically begins to work by the immediate rising of the steelyard; and as it rises the poise weight commences to travel forward, and this continues until the weight of it is sufficient (owing to the added leverage it has gained)

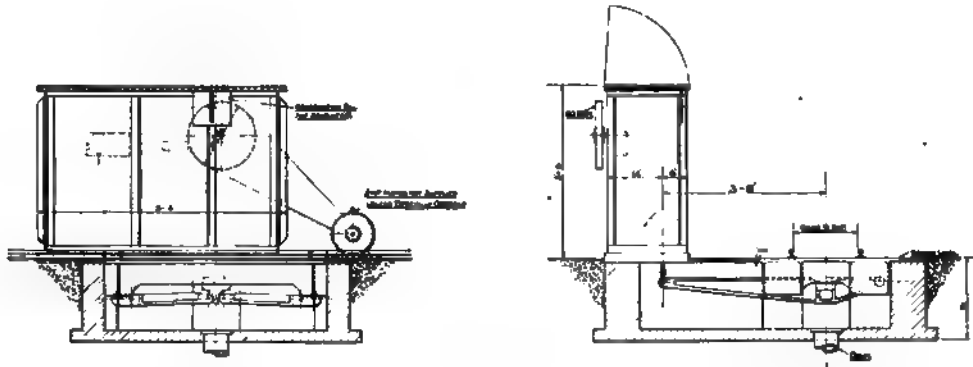


Figs. 1137 and 1138. Avery's Automatic Hopper Weigher.

to overcome the weight of the coal in the weigh hopper, when the steelyard will fall and be in equilibrium. Connected to the poise weight by gearing is a special counter which records and adds together the weight of the coal. As soon as the weighing operation has been completed, the discharging gear comes into action, causing the door of the weigh hopper to open and discharge its contents into the shoot below. When the last piece of coal has left the weigh hopper the door automatically shuts and locks itself, ready for the next weighing, and simultaneously the poise weight upon the steelyard returns to the starting point. No feed valves are required; consequently this machine will weigh any size pieces from nuts to the largest lumps. The power required for operating this machine may be obtained from a small motor of $\frac{1}{2}$ H.P. The figures indicated by the totalling counter are read by the person in charge at the commencement of weighing each barge load, etc., and again at the finish. The difference between the two accounts, of course, represents the sum total of the coal carried by that particular barge or truck.

Avery's Patent Automatic Truck Weighbridge and Totaliser.—This machine is illustrated in Figs. 1139 and 1140. It automatically weighs all trucks brought on to the platform and registers the weights upon a special counter, so that

the total net weight of material passed over the track during any period can be seen at a glance. The number of trucks weighed is also automatically recorded. Only $\frac{1}{4}$ H.P. is required to operate the mechanism. A loaded truck coming upon the weigh-bridge automatically sets the mechanism in action, while empty trucks or people



Figs. 1139 and 1140. Avery's Automatic Truck Weighbridge.

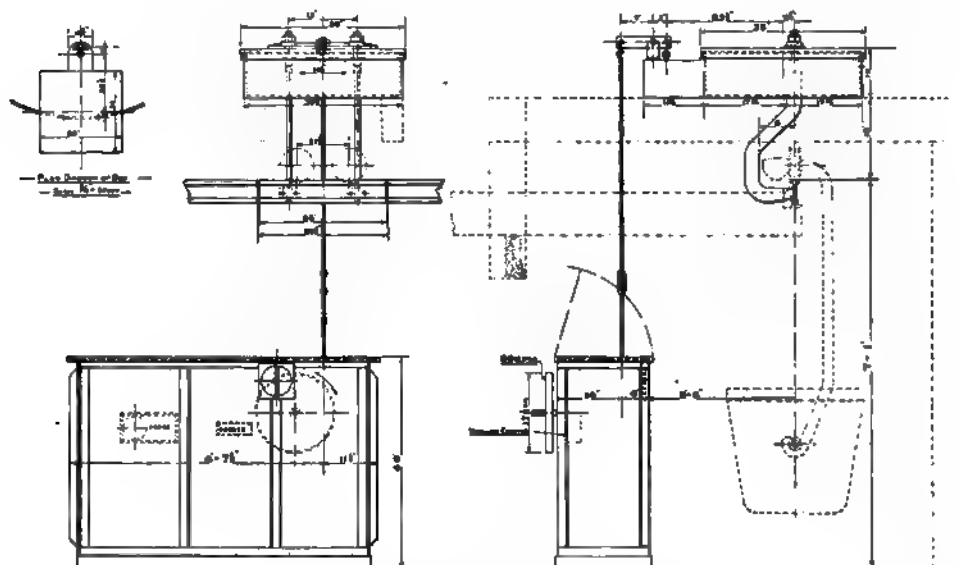
passing over the platform have no effect upon the records. These machines are built for any size of truck and gauge of rail, and can be fitted with a system of truck controllers which prevents the same truck being weighed twice over. If it is desired to record the weight of each individual load instead of the total weight this

Fig. 1141. Avery's Automatic Pit-Bank Weighing Machine.

machine can also be fitted with printing mechanism. The weighing is then performed automatically as usual, but it is necessary to pull a handle after each weighing in order to print the weight upon a ticket or roll of paper. The weight thus recorded is determined solely by the machine and is beyond the control of the person who pulls the printing handle.

Avery's Automatic Self-Indicating Weighing Machine.—This device has been designed to facilitate the rapid weighing of trains of loaded colliery and mining trucks which must all be balanced to the same tare weight; the actual net weight of the coal or ore is indicated automatically by the machine itself, which is illustrated in Fig. 1141.

A minimum weight of coal is decided upon, and this is balanced on the steel-yard, and the quadrant usually indicates up to 5 cwt. over that weight, thus allowing a variation of 5 cwt. in the amount of coal in each truck. For example, if the fixed



Figs. 1142 and 1143. Avery's Automatic Overhead Weigher.

minimum weight is 25 cwt. the quadrant is marked from 25 to 30 cwt., and any weight between these limits is indicated automatically on the quadrant, and can be read off at a glance. The range of weighings can be altered to suit requirements.

Avery's Patent Automatic Overhead Weigher and Totaliser.—Figs. 1142 and 1143 show a machine very similar to the automatic weighbridge previously described, but it is designed to suit an overhead track. It can be attached to runways of all descriptions, and is especially suitable for weighing buckets carried by a ropeway. This machine is also fitted with a totalling counter which automatically registers the net weight of material carried; the number of weighed buckets is also recorded.

CHAPTER XLIV

TABLE GIVING WEIGHTS OF VARIOUS MATERIALS

	Lb. per Cubic Foot.	Cubic Feet per Ton.	Lb. per Bushel.
Ashes, coal - - - - -	44	51	...
Asphalt, solid - - - - -	156	14.35	...
*Asphalt, broken, loose - - - - -	120	18.6	...
*Ballast, loose - - - - -	112	20	...
Barley - - - - -	39	57.5	50
Barley meal - - - - -	35	64	45
Basalt, solid - - - - -	189	11.85	...
*Basalt, broken - - - - -	170	13	...
Bath stone - - - - -	123	18.2	...
Beans, horse - - - - -	50	45	64
Beans, white - - - - -	47	48	60
Bean meal - - - - -	43	52	56
Beet (sugar) - - - - -	38	59.25	48
Blue Lias, solid - - - - -	154	14.5	...
*Blue Lias, broken - - - - -	140	16	...
Bones - - - - -	50 to 70	32 to 45	...
Bone meal - - - - -	56	40	...
Bones, calcined - - - - -	23	95.5	...
Bone charcoal, wet - - - - -	60	37.33	...
Buck wheat - - - - -	37	61	47
Castor beans - - - - -	36	62	46
Cement clinker - - - - -	100	22.4	...
Cement, fine - - - - -	120	18.7	...
Cement, Portland - - - - -	86 to 90	26 to 22.6	...
Cement, Roman - - - - -	100	22.4	...
Chalk, solid - - - - -	125 to 150	18 to 15	...
*Chalk, lumps - - - - -	77	29	...
Clay, solid - - - - -	80 to 120	28 to 18.5	...
*Clay, stiff, loose - - - - -	78	28	...
Clay-shale, solid - - - - -	155	14.45	...
*Clay-shale, broken - - - - -	93	24	...
Clover seed - - - - -	47	48	60
*Coal, average mixed broken - - - - -	50	45	...
Coal, anthracite, solid - - - - -	95	23.5	...
*Coal, anthracite, loose - - - - -	53	42.3	...
Coal, bituminous, solid - - - - -	78	29	...
*Coal, bituminous, loose - - - - -	50	45	...
Coal, Cannel - - - - -	79	30	...
*Coal, Cannel, loose - - - - -	50	45	...
*Coal, Welsh, loose - - - - -	52	43	...

* The weights of these materials are only approximate, and vary greatly with the size of the pieces.

	Lb. per Cubic Foot.	Cubic Feet per Ton.	Lb. per Bushel.
*Coal, Scotch, loose - - - -	53	42	...
*Coal, Newcastle, loose - - - -	48·7	46	...
*Coal, Lancashire, loose - - - -	48·6	46	...
*Coal, Derbyshire, loose - - - -	56·6	48	...
*Coal charcoal, loose - - - -	18	124	...
*Coke, broken - - - -	30	80	...
Concrete - - - -	120	18·7	...
Coprolites - - - -	100	22·4	...
Cotton seed - - - -	36	62	46
Derby-stone, solid - - - -	150	15	...
*Derby-stone, broken - - - -	135	16·6	...
Earth, loose, average - - - -	78	28·7	...
Earth, mould, average - - - -	74	30·2	...
Flax seed - - - -	43	52	56
Flour - - - -	43	52	56
Flaked maize malt - - - -	10	240	12
Granite, solid - - - -	165	13·5	...
*Granite, broken - - - -	150	15	...
Grass seed - - - -	11	48	14
Gravel, average - - - -	109	21	...
Gravel, coarse - - - -	98	23	...
Graphite - - - -	140	16	...
Gypsum, solid - - - -	143	15·4	...
*Gypsum, broken - - - -	120	18·7	...
Gypsum, plaster of Paris - - - -	105	21·25	...
Hemp seed - - - -	30	74	44
Horse beans - - - -	50	45	64
Ice - - - -	58	38	...
*Ice, broken - - - -	50	45	...
Indian corn - - - -	45	49	58
Indian corn, meal - - - -	41	54	53
Iron ore, Clydesdale - - - -	190	12	...
Iron ore, brown - - - -	236	9·5	...
Iron ore, red - - - -	320	7	...
Lias, broken - - - -	140	16	...
Limestone, solid - - - -	161	20	...
*Limestone, broken - - - -	90	25	...
Lime, quick - - - -	53	42	...
Linseed - - - -	37	61	53
Locust beans - - - -	23	97	29
Logwood, fine - - - -	18	124·5	...
Maize - - - -	45	49	58
Maize meal - - - -	41	54	53
Malt - - - -	30	74	38
Malt, green - - - -	17	131	...
Manure, artificial - - - -	56	40	...
Marble, average - - - -	169	13·2	...
Marl - - - -	79	28	...
Mortar - - - -	86	26	...
Mud, dried - - - -	95	23·5	...
Mud, damp, pressed - - - -	115	19·5	...

* The weights of these materials are only approximate, and vary greatly with the size of the pieces.

TABLE GIVING WEIGHTS OF VARIOUS MATERIALS

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	Lb. per Cubic Foot.	Cubic Feet per Ton.	Lb. per Bushel.
Mud, wet, fluid - - - - -	110	20.5	...
Oats - - - - -	30	75	40
Oat meal - - - - -	39	57.5	50
Ore, pulverised, average - - - - -	220	10	...
Oxide of iron - - - - -	55	40	...
Paper (wet) as from revolving drums used for making paper boards - - - - -	57	38.9	...
Peas - - - - -	50	45	64
Pea meal - - - - -	43	52	56
Peat, dry - - - - -	11	200	...
Phosphate - - - - -	100	22.22	...
Phosphate meal - - - - -	110	20	...
Pitch - - - - -	60	37	...
Plaster - - - - -	98	23	...
Plaster of Paris - - - - -	105	21.25	...
Plumbago - - - - -	140	16	...
Portland cement - - - - -	86 to 90	26 to 22.6	...
Portland stone - - - - -	150	15	...
*Portland stone, broken - - - - -	142	15.8	...
Potatoes - - - - -	47	48	60
Quartz - - - - -	150	15	...
*Quartz, broken - - - - -	142	15.8	...
Quartz sand - - - - -	170	13	...
Quick lime - - - - -	53	42	...
Rape seed - - - - -	36	61	40
Rye - - - - -	41	55	53
Salt, rock, solid - - - - -	131	17	...
Salt, dried - - - - -	56	40	...
Salt, cake - - - - -	70	32	...
Salt, fine - - - - -	42	52	56
Salt, coarse - - - - -	45	50	...
Sand, river - - - - -	117	19	...
Sand, pit, fine - - - - -	95	23.5	...
Sand, pit, coarse - - - - -	100	22.5	...
Sand, moulding - - - - -	77	29	...
Sandstone, solid - - - - -	150	15	...
*Sandstone, broken - - - - -	140	16	...
Shingle - - - - -	88	24.5	...
Slate - - - - -	157	14.2	...
Snow, fresh fallen - - - - -	6	380	...
Sugar, lump - - - - -	60	37.5	...
Sugar, crystal - - - - -	56	40	...
Sugar, fine - - - - -	55	40.7	...
Sugar, brown - - - - -	55	40	...
Timothy seed - - - - -	35	63	45
Turnips - - - - -	43	52	55
Water, fresh - - - - -	62.42	35.88	...
Water, sea - - - - -	64	35	...
Wheat - - - - -	47	48	60
Yorkshire stone - - - - -	154	14.5	...
*Yorkshire stone, broken - - - - -	142	15.9	...

* The weights of these materials are only approximate, and vary greatly with the size of the pieces.

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TRADE DIRECTORY

Of Firms of Repute who are Makers of the different Machines for the Mechanical Handling and Storing of Material

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Ewart Chainbelt Co., Ltd., Colombo Street, Derby.
Jenkins, W. J., & Co., Ltd., Beehive Works, Retford, Notts.
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Simon, Henry, Ltd., 20 Mount Street, Manchester.
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